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CONTENTS.

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The Anthracotheiidæ of the Dera Bugti deposits in Baluchistan: Vol. VIII, Memoir No. 2 (1924), pp. 59, pls. 7, by C. Forster Cooper. Price 4 Rs.

The Perissodactyla of the Eocene of Burma: Vol. VIII, Memoir No. 3 (1925), pp. 28, pls. 2, by Dr. G. E. Pilgrim. Price 1 Re. 9 As.

The Fossil Suidæ in India: Vol. VIII, Memoir No. 4 (1926), pp. 65, pls. 20, by Dr. G. E. Pilgrim. Price 11 Rs. 12 As.

On the Blake Collection of Ammonites from Kachh: Vol. IX, Memoir No. 1 (1924), pp. 29, by L. F. Spath. Price 12 As.

Revision of the Jurassic Cephalopod Fauna of Kachh (Cutch): Vol. IX, Memoir No. 2. Part I (1927), pp. 71, pls. 1-7, price 4 Rs. 12 As.: Part II (1928), pp. 73-161, pls. 8-19, price 7 Rs. 14 As.: Part III (1928), pp. 163-278, pls. 20-47, price 15 Rs. 4 As.: Part IV (1931), pp. 279-550, pls. 48-102, price 34 Rs. 12 As.: Part V (1931), pp. 551-658, pls. 103-124, price 12 Rs. 14 As.: Part VI (1933), pp. i-vii, pp. 659-945, pls. 125-130, price 13 Rs. 8 As.; by L. F. Spath.

Palæozoic and Mesozoic Fossils from Yunnan: Vol. X, Memoir No. 1 (1927), pp. 291, pls. 20, by F. R. C. Reed. Price 20 Rs. 9 As.

The Mollusca of the Ranikot Series (together with some species from the Cardita Beaumonti Beds): Vol. X, Memoir No. 2 (1927), pp. 31, pls. 4, by M. Cossmann, and G. Pisarro, revised by the late Mr. E. Vredenburg, with an introduction and editorial notes by Dr. G. de P. Cotter. Price 2 Rs. 6 As.

Les Couches à Cardita Beaumonti: Vol. X, Memoir No. 3. Les Couches à Cardita Beaumonti dans le Bélouchistan: Fasc. I (1928), pp. 25, pls. 4, price 2 Rs. 12 As.: Les Couches a Cardita Beaumonti dans le Sind: Fasc. II (1929), pp. 27-73, pls. 5-11, price 4 Rs. 8 As.; by Prof. Henri Douvillé.

A Supplement to the Mollusca of the Ranikot Series: Vol. X, Memoir No. 4 (1928), pp. 75, pls. 9, by the late E. W. Vredenburg, edited with notes by Dr. G. de P. Cotter. Price 6 Rs. 12 As.

Revisions of Indian Fossil Plants: Vol. XI. Coniferales (a. Impressions and Incrustations): Part I (1928), pp. 1-49, pls. 1-6, price 3 Rs. 12 As.: Coniferales (b. Petrifactions): Part II (1931), pp. 51-124, pls. 7-15, price 7 Rs. 6 As.: by Prof. B. Sahni.

The Fauna of the Agglomeratic Slate Series of Kashmir: Vol. XII (1928), pp. 42, pls. 8, by the late H. S. Bion, with an Introductory Chapter by C. S. Middlemiss. Price 6 Rs. 8 As.

The Artiodactyla of the Eocene of Burma : Vol. XIII (1928), pp. 39, pls. 4, by Dr. G. E. Pilgrim. Price 3 Rs. 12 As.

A Sivapithecus Palate and other Primate Fossils from India : Vol. XIV (1927), pp. 24, pl. 1, by Dr. G. E. Pilgrim. Price 1 Re. 8 As.

The Fossil Fauna of the Samana Range and some Neighbouring Areas : Vol. XV, An Introductory Note : Part I (1930), pp. 15, pls. 1-4, price 1 Re. 4 As.; by Lt.-Col. L. M. Davies, R.A., F.G.S. The Albian Echinoidea : Part II (1930), pp. 17-23, pl. 4a, price 12 As.; by Ethel D. Currie, B.Sc., Ph.D., F.G.S. The Brachiopoda : Part III (1930), pp. 25-37, pls. 5-6, price 1 Re. 4 As.; by Helen Marguerite Muir-Wood, M.Sc., F.G.S. Lower Albian Gastropoda and Lamellibranchia : Part IV (1930), pp. 39-49, pl. 7, price 14 As.; by L. R. Cox, M.A., F.G.S. The Lower Cretaceous Ammonoidea ; with Notes on Albian Cephalopoda from Hazara : Part V (1930), pp. 51-66, pls. 8-9, price 1 Re. 6 As.; by L. F. Spath, D.Sc., F.G.S. The Palaeocene Foraminifera : Part VI (1930), pp. 67-79, pl. 10, price 14 As.; by Lt.-Col. L. M. Davies R.A., F.G.S. The Lower Eocene Corals : Part VII (1930), pp. 81-128, pls. 11-16, price 3 Rs. 14 As.; by J. W. Gregory, LL.D., D.Sc., F.R.S. The Mollusca of the Hangu Shales : Part VIII (1930), pp. 129-222, pls. 17-22, price 4 Rs. 14 As.; by L. R. Cox, M.A., F.G.S.

Upper Carboniferous Fossils from Tibet : Vol. XVI (1930), pp. 37, pls. 4, by F. R. C. Reed. Price 3 Rs. 6 As.

New Fossils from the Productus Limestones of the Salt Range, with notes on other species : Vol. XVII (1931), pp. 56, pls. 8, by F. R. C. Reed. Price 5 Rs. 6 As.

The Fossil Carnivora of India : Vol. XVIII (1932), pp. 232, pls. 10, by Dr. G. E. Pilgrim. Price 13 Rs. 12 As.

Upper Carboniferous Fossils from Afghanistan : Vol. XIX (1931), pp. 39, pls. 4, by F. R. C. Reed. Price 3 Rs. 10 As.

New Fossils from the Agglomeratic Slate of Kashmir : Vol. XX, Memoir No. 1 (1932), pp. 79, pls. 12, by F. R. C. Reed. Price 8 Rs. 4 As.

Homoxylon rajmahalense, gen. et sp. nov., a fossil angiospermous wood, devoid of vessels from the Rajmahal Hills, Behar : Vol. XX, Memoir No. 2 (1932), pp. 19, pls. 2, by Prof. B. Sahni. Price 1 Re. 12 As.

A petrified Williamsonia (W. sewardiana, sp. nov.) from the Rajmahal Hills, India : Vol. XX, Memoir No. 3 (1932), pp. 19, pls. 3, by Prof. B. Sahni. Price 2 Rs. 2 As.

The Jurassic and Cretaceous Ammonites and Belemnites of the Attock District : Vol. XX, Memoir No. 4 (1934), pp. 39, pls. 6, by L. F. Spath. Price 4 Rs.

The Triassic, Jurassic and Cretaceous Gastropoda and Lamellibranchia of the Attock District, Vol. XX, Memoir No. 5 (1935), pp. 27, pls. 2, by L. R. Cox. Price 1 Re. 14 As.

The Mesozoic Brachiopoda of the Attock District : Vol. XX, Memoir No. 6, (1937) pp. 34, pl. 1, by Helen M. Muir-Wood. Price 2 Rs. 2 As.

The Cretaceous Saurischia and Ornithischia of the Central Provinces of India : Vol. XXI, Memoir No. 1 (1933), pp. 74, pls. 24, by Prof. Friedrich Baron von Huene and Dr. C. A. Matley. Price 13 Rs. 8 As.

Cambrian and Ordovician Fossils from Kashmir : Vol. XXI, Memoir No. 2 (1934), pp. 38, pls. 2, by F. R. C. Reed. Price 2 Rs. 8 As.

The Lower Palaeozoic Faunas of the Southern Shan States : Vol. XXI, Memoir No. 3 (1936), pp. 130, pls. 7, by F. R. C. Reed. Price 7 Rs. 10 As.

Fossil Algae from the Uppermost Cretaceous beds (the Niniyur group) of the Trichinopoly District, S. India : Vol. XXI, Memoir No. 4 (1936), pp. 49, pls. 6, by Profs. L. Rama Rao and Julius Pia. Price 4 Rs. 10 As.

Echinoidea of the Persian Gulf : Vol XXII, Memoir No. 1 (1933), pp. 35, pls. 3, by E. L. G. Clegg. Price 2 Rs. 8 As.

Fossil Mollusca from Southern Persia (Iran) and Bahrein Island : Vol. XXII, Memoir No. 2 (1936), pp. 69, pls. 8; by L. R. Cox. Price 5 Rs. 8 As.

On Bajocian Ammonites and Belemnites from Eastern Persia (Iran) : Vol. XXII, Memoir No. 3 (1936), pp. 21, pl. 1, by L. F. Spath. Price 1 Re. 2 As.

Cambrian Trilobites from Iran (Persia) : Vol. XXII, Memoir No. 5 (1937), pp. 22, pls. 2, by Prof. W. R. King. Price 1 Re. 14 As.

A Permo-Carboniferous Fauna from South-West Persia (Iran) : Vol. XXII, Memoir No. 6 (1936), pp. 59, pls. 5, by J. A. Douglas. Price 4 Rs. 4 As.

Some Fossils from the Eurydesma and Conularia Beds (Punjabian) of the Salt Range : Vol. XXIII, Memoir No. 1 (1936), pp. 36, pls. 5, by F. R. C. Reed. Price 3 Rs. 14 As

Eocene Beds of the Punjab Salt Range : Vol. XXIV, Memoir No. 1 (1937), pp. 79, pls. 7, by Lt.-Col. L. M. Davies and E. S. Pinfold. Price 6 Rs. 2 As.

The Cephalopoda of the Neocomian Belemnite Beds of the Salt Range : Vol. XXV, Memoir No. 1 (*in the Press*), by L. F. Spath.

Index to the Genera and Species described in the Palaeontologia Indica, up to the year 1891. Price 1 Re.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1938. [March

General Report of the Geological Survey of India for the year 1937. By A. M. Heron, D.Sc., F.G.S., F.R.G.S., F.R.S.E., F.R.A.S.B., F.N.I., *Director, Geological Survey of India.*

CONTENTS.

DISPOSITION LIST.

DURING the period under report the officers of the Department were employed as follows:—

Superintending Geologists.

DR. C. S. FOX . . . Returned from the field in Assam on the 20th February, 1937. Granted leave out of India on average pay from the 16th March, 1937, to the 23rd November, 1937. Attended the XVIIth session of the International Geological

Congress in Russia in interruption of leave from the 1st July, 1937, to the 31st July, 1937. On return from leave placed in charge of the North-eastern Circle and continued the geological survey of the Garo Hills district, Assam. Left for the field on the 11th December, 1937.

MR. E. L. G. CLEGG . Continued in charge of the Burma Circle, working near Mandalay and Thabeitkyin. Placed on foreign service in Burma from the 1st April, 1937, in charge of the Burma Geological Department. Returned from the field on the 17th April, 1937. Granted combined leave out of India from the 1st June to the 14th November, 1937.

MR. H. CROOKSHANK . Continued in charge of the Southern Circle, mapping in the Bastar State. Investigated the water-supply problem of Belgaum cantonment and visited a deposit of copper-ore near Udaigiri in the Nellore district between the 12th and 23rd January, 1937. Returned to headquarters on the 4th May, 1937. Left for the field on the 7th November, 1937, to continue his systematic survey of the Bastar State. Visited the Kerendi Hill, Jubbulpore, in connection with a water-supply problem on the 24th November, 1937.

DR. A. L. COULSON . Geological survey in the North-West Frontier Province and in charge of the North-western Circle. Investigated the water-supply problems of certain areas in Baluchistan between the 4th and 9th January, 1937. Visited the Makerwal Colliery from the 4th to

the 6th February, 1937. Examined the Malakand Hydro-electric works between the 18th and the 20th March, 1937. Returned from the field on the 19th August, 1937.

Geologists.

MR. E. J. BRADSHAW — Continued as Resident Government Geologist, Yenangyaung, and official member of the Advisory Board of the Yenangyaung and Singu Oilfields. Placed on foreign service under the Government of Burma from the 1st April, 1937. Officiated as Superintending Geologist from 1st June to 14th November, 1937.

MR. D. N. WADIA — At headquarters. Officiated as Superintending Geologist *vice* Dr. Fox on leave and held charge of the North-eastern Circle from the 16th March, 1937, to the 23rd November, 1937. Attached to the North-western Circle to continue his previous work in Kashmir and Jammu State.

DR. J. A. DUNN — Remained at headquarters as Petrologist.

MR. E. R. GEE — Continued in charge of the office as Assistant Director till the 29th April, 1937. Visited the salt mines of Khewra, Chanuwala, Makrach and Kalabagh and the Makerwal Colliery between the 25th January, 1937 and the 7th February, 1937. Examined a well site at Tinpahar in Santal Parganas and visited the sandstone quarries of Mangal Hat on the 24th February, 1937. Granted leave out of India on average pay for 6 months combined with study leave for 12 months from the 30th April, 1937.

MR. W. D. WEST . .	Mapping in the Central Provinces. Examined the Pench River dam site between the 11th and the 14th January, 1937. Visited Rewa State in connection with a hydro-electric scheme from the 13th to the 19th February, 1937. Returned to headquarters on 20th February, 1937. As member of the North-western Circle left for field work in the Simla Hills on the 1st March, 1937. Returned to Calcutta on the 25th April, 1937, and placed in charge of the office as Assistant Director from the 30th April, 1937.
DR. M. S. KRISHNAN	Relinquished office as member of the Coal Mining Committee and resumed charge of his duties in the Geological Survey of India on the 10th April, 1937. Attached to the Southern Circle to work in Singhbhum and in the Eastern States Agency. Left for the field on the 19th November, 1937.
MR. J. B. AUDEN . .	Mapping in the Mussoorie Himalayas. Returned to headquarters on the 10th April, 1937. Left for work with the Karakoram Expedition on the 29th April, 1937, and returned on the 10th September, 1937. Granted combined leave out of India for 11 months and 24 days from the 21st October, 1937.
MR. V. P. SONDHI	Returned to Rangoon after work with the Sino-British Boundary Commission to the Wa States on the 22nd May, 1937. Arrived in Calcutta on transfer on the 27th May, 1937. Granted combined leave out of India for 16 months and 16 days from the 19th June, 1937.
DR. P. K. GHOSH	Returned to headquarters from the Bastar State on the 21st April, 1937.

Attached to the Southern Circle to work in the Bastar State. Left for the field on the 15th November, 1937.

DR. M. R. SAHNI . Remained at headquarters as Palæontologist.

MR. A. M. N. GHOSH Returned from the field on the 7th May, 1937. Attached to the North-eastern Circle for work in the Khasi and Jaintia Hills district, Assam. Left for the field on the 28th December, 1937.

DR. B. C. ROY Appointed Geologist, Geological Survey of India, and joined the Department from the 13th May, 1937. Attached to the Southern Circle. Left for field work in the Jubbulpore district on the 7th November, 1937, and returned to headquarters on the 26th November, 1937. Detailed for work in the Eastern States Agency.

Chemist.

DR. R. K. DUTTA ROY Remained at headquarters.

Assistant Geologists.

MR. D. BHATTACHARJI Returned from the field on the 2nd May, 1937. Attached to the Southern Circle for work in the Balaghat district, and in the Khairagarh and Kawardha States, C. P. Left for the field on the 14th November, 1937.

MR. B. C. GUPTA Returned from the field on the 29th April, 1937. Granted leave on average pay for 1 month and 24 days from the 25th May, 1937. Attached to the Southern Circle and detailed to continue geological survey in the Drug district and in the Nandgaon State, C. P. Left for the field on the 15th November, 1937.

MR. H. M. LAHIRI	Examined the underground water-supply problem of the Nurpur tahsil in the Kangra district on the 18th and 19th January, 1937. Returned from the field on the 9th May, 1937. Attached to the North-western Circle and left for geological survey work in the Kangra and Gurdaspur districts and the Chamba State, Punjab, on the 18th November, 1937.
DR. L. A. N. IYER	Returned from the field to Rangoon on the 1st March, 1937. Arrived in Calcutta on transfer on the 4th March, 1937. Granted leave on average pay from the 5th March, 1937, to the 22nd March, 1937, and again from the 20th May, 1937, to the 27th July, 1937. Attached to the Southern Circle and left for field work in the Ratnagiri district, Bombay, on the 26th November, 1937.
MR. P. N. MUKERJEE	Returned from leave out of India on the 28th June, 1937. At headquarters to assist the Palæontologist in the bringing up to date the fossil galleries of the Indian Museum. Attached to the North-eastern Circle for work in the Khasi and Jaintia Hills district, Assam.
DR. A. K. DEY	On foreign service in Jashpur State. Returned from the field to Calcutta on the 4th May, 1937. Left for field work in Jashpur State on the 15th November, 1937.
MR. V. R. R. R. KHEDKER	Returned to headquarters from camp on the 12th May, 1937. Attached to the North-eastern Circle to carry on geological mapping in the Khasi and Jaintia Hills district, Assam. Left for the field on the 2nd December, 1937.

MR. P. C. DAS HAZRA — Returned from the field on the 21st May, 1937. Attached to the North-western Circle to continue his geological mapping in the Kashmir and Jammu State and also to visit Poonch State and Gurdaspur district, Punjab. Left for the field on the 18th November, 1937.

Artist.

MR. S. RAY . . . Remained at headquarters. Granted earned leave for 12 days from the 21st October, 1937.

Curator.

P. C. ROY . . . At headquarters.

Field Collector.

N. K. N. AIYENGAR . At headquarters till the 5th February, 1937. Left for the field on the 6th February, 1937, for collecting fossil specimens in the Parasia coalfield and other localities in the Chhindwara and Narsinghpur district, Central Provinces. Returned on the 13th March, 1937 and remained at headquarters.

A. B. DUTT . . Officiated as Assistant Geologist *vice* Dr. A. K. Dey on foreign service and continued geological survey work in Burma. Placed on foreign service under the Government of Burma from the 1st April, 1937. Returned from the field on the 30th April, 1937. Left for work in Burma on the 16th November, 1937.

Assistant Chemist.

MAHADEO RAM . Returned from leave on the 28th January, 1937, and remained at headquarters.

Museum Assistants.

D. GUPTA . . . . At headquarters.

M. S. VENKATRAM . Continued to officiate as Field Collector. Returned to this Department from the Coal Mining Committee on the 21st April, 1937, and remained at headquarters.

V. BHASKARA RAO . At headquarters. Granted leave without pay for six and a half months from the 14th September, 1937.

2. The cadre of the Department, at the end of the year, consisted of 4 Superintending Geologists, 12 Geologists and 1 Chemist.

ADMINISTRATIVE CHANGES.

3. From the date of separation of Burma from India, 1st April. 1937, the Burma Circle, consisting of Messrs. Clegg. Bradshaw and Dutt, became the Burma Geological Department.

Promotions and appointments.

Mr. E. J. Bradshaw officiated as Superintending Geologist from the 1st June to the 14th November, 1937, *vice* Mr. E. L. G. Clegg on leave.

Mr. D. N. Wadia officiated as Superintending Geologist from the 16th March, 1937, to the 23rd November. 1937, *vice* Dr. C. S. Fox on leave.

Dr. B. C. Roy, B.Sc. (Cal.), A.I.S.M., D.I.C., M.Sc. (Lond)., Dr. Ing. (Freiburg), was appointed Geologist with effect from the 13th May, 1937.

Mr. A. B. Dutt continued to officiate as Assistant Geologist during the year *vice* Dr. A. K. Dey on foreign service in Jashpur State.

Leave.

4. Dr. C. S. Fox was granted leave out of India on average pay from the 16th March, 1937, to the 23rd November, 1937.

Mr. E. L. G. Clegg was granted combined leave out of India from the 1st June to the 14th November, 1937.

Mr. E. R. Gee was granted leave out of India on average pay for 6 months combined with study leave for 12 months with effect from the 30th April, 1937.

Mr. J. B. Auden was granted leave out of India on average pay for 2 months combined with leave on half average pay for 6 months

and study leave for 3 months and 24 days with effect from the 21st October, 1937, with permission to prefix the Puja holidays.

Mr. V. P. Sondhi was granted leave out of India on average pay for 4 months and 16 days combined with study leave for 12 months with effect from the 19th June, 1937.

Mr. B. C. Gupta was granted leave on average pay from the 25th May, 1937, to the 18th July, 1937.

Dr. L. A. N. Iyer was granted leave on average pay for 18 days from the 5th March, 1937, and again for 2 months and 8 days with effect from the 20th May, 1937.

HONOURS AND AWARDS.

5. The title of Rai Sahib was awarded to Mr. N. K. Ghosh, Chief Clerk of this Department.

The following members of this Department received the Coronation Medal :—

(1) Dr. A. M. Heron, Director.
(2) Dr. C. S. Fox, Superintending Geologist.
(3) Mr. E. L. G. Clegg, Superintending Geologist.
(4) Mr. H. Crookshank, Superintending Geologist.
(5) Dr. A. L. Coulson, Superintending Geologist.
(6) Mr. E. J. Bradshaw, Geologist.
(7) Mr. D. N. Wadia, Geologist.
(8) Dr. J. A. Dunn, Geologist.
(9) Mr. D. Bhattacharji, Assistant Geologist.
(10) Rai Sahib N. K. Ghosh, Chief Clerk.
(11) Babu M. N. Chatterjee, First Assistant.

The Government of India prize of Rs. 500 awarded annually by the Council of the Mining, Geological and Metallurgical Institute of India for 'the best paper by a member read before the Institute and published in the *Transactions* each year' was awarded for the year ending the 31st October, 1936 to Mr. W. Gilbert, Reliance Firebrick and Pottery Co., Ltd., Barakar, for his paper entitled 'Some Aspects of the Ceramic Industry'. The Institute Gold Medal was presented to Mr. E. R. Gee for his paper entitled 'Economic Geology of the Northern Punjab with notes on adjoining portions of the North-West Frontier Province'.

LECTURESHIP.

6. Dr. J. A. Dunn continued to act as part-time Professor of Geology at the Presidency College, Calcutta, during the year 1937.

POPULAR LECTURES.

7. The following popular lectures were delivered by officers of the Department during the year :—

(1) 'Waziristan' by Dr. A. L. Coulson, at a meeting of the Mining, Geological and Metallurgical Institute of India, Calcutta.

(2) 'Siwalik Sedimentation' by Dr. A. L. Coulson, as Presidential Address to the Annual General Meeting of the Geological Institute, Presidency College, Calcutta.

(3) 'The Uranium and Radium Resources of the World' by Dr. M. S. Krishnan, at a meeting of the Geological Institute, Presidency College, Calcutta.

(4) 'A Geologist in the Mishmi Hills' by Mr. A. M. N. Ghosh, at a meeting of the Geological Institute, Presidency College, Calcutta.

(5) 'A Geologist in Russia' by Dr. C. S. Fox, at a Special General Meeting of the Geological Institute, Presidency College, Calcutta.

(6) 'Where Burma meets Siam' by Dr. A. M. Heron, at a meeting of the Geological Institute, Presidency College, Calcutta.

(7) 'Earthquakes' by Dr. M. S. Krishnan, at the University of Madras.

EXHIBITIONS.

Popular exhibits.

8. Exhibits of a popular character, such as collections of palæolithic implements or series of fossils illustrating progressive evolution or retrogression, have found a place either in the fossil galleries or in the visitors' waiting room of the Geological Survey, and have attracted considerable attention.

Exhibits for the Science Congress.

For the benefit of the delegates to the Jubilee Session of the Indian Science Congress, representative collections of typical vertebrate, invertebrate and plant fossils and rocks were exhibited at the Geological Survey Office and evoked much interest.

CONGRESS.

9. In interruption of leave in England, Dr. C. S. Fox attended the XVIIth session of the International Geological Congress held in Russia from the 1st July, 1937, to the 31st July, 1937.

PUBLICATIONS.

10. The following publications were published during the year under report :—

1. Records, Vol. 71, Part 4.
2. Records, Vol. 72. Part 1.
3. Records. Vol. 72, Part 2.
4. Records, Vol. 72, Part 3.
5. Memoirs, Vol. LXIX, Part 1.
6. Memoirs. Vol. 71.
7. Palæontologia Indica, New Series, Vol. XX, Memoir No. 6.
8. Palæontologia Indica, New Series, Vol. XXII. Memoir No. 5.
9. Palæontologia Indica. New Series. Vol. XXII, Memoir No. 6.
10. Palæontologia Indica, New Series, Vol. XXIV, Memoir No. 1.

LIBRARY.

11. The additions to the Library amounted to 3,113 volumes, of which 1,100 were acquired by purchase and 2,013 by presentation and exchange.

DRAWING OFFICE.

12. Mr. S. Ray was in charge of the Drawing Office throughout the year, except for a period of 12 days from the 21st October to 1st November, when he was on leave on average pay.

Publications.

13. During the year 135 halftone and line blocks and 9 litho stones were prepared for plates for the *Records*, *Memoirs* and *Palæontologia Indica*, and 67 plates were printed off; 193 drawings, maps and diagrams and 31 line blocks for text-figures were also made.

The number of geologically coloured originals received from officers totalled 82, while 1914 topographical sheets were received from the Director, Map Publication, Survey of India, and 600 were issued for departmental use.

Photographic section.

14. The photographic section was fully occupied with copying, developing, enlarging and printing work for publications and reports. The number of negatives received into stock (registered) totalled 126, while 2,143 photographic prints and enlargements were made. In addition, 105 lantern slides were made.

MUSEUM AND LABORATORY.

15. Dr. J. A. Dunn continued to act as Petrologist throughout the year. Mr. Purna Chandra Roy continued as Curator of the Geological Museum and Laboratory.

16. Messrs. Dasarathi Gupta, M.R.Ry. V. Bhaskara Rao and B. G. Deshpande continued as Museum Assistants. Mr. V. Bhaskara Rao officiated as Field Collector till 20th April, 1937 and reverted as Museum Assistant on the 21st April, 1937 on the return of Mr. M. S. Venkatram from deputation with the Coal Mining Committee. Mr. P. K. Chatterjee was appointed to act as Museum Assistant from the 8th January, 1937 to the 20th April, 1937 in place of Mr. V. Bhaskara Rao and continued again to act as Museum Assistant from the 14th September, 1937 in place of Mr. V. Bhaskara Rao who went on leave from that date. Babu Mahadeo Ram continued as Assistant Chemist throughout the year.

17. The number of specimens determined in the laboratory amounted to 611, of which 82 were quantitatively analysed or otherwise specially tested. The corresponding figures for the previous year were 737 and 137 respectively. Much of the analytical work was of a specialised character. During the year the laboratory worked to full capacity on the chemical analysis of specimens. Rearrangements in the laboratory were completed. Rock-section cutting machinery and an automatic polishing machine were installed and are working successfully. These became necessary in consequence of the large number of sections required. A petrological examination of a large suite of specimens from Bawdwin Mine, Northern Shan States, and from Mawchi Mine, Southern Shan States, was made.

18. During the year reconditioning of the show-cases in the museum was continued, as also the rearrangement of stored rock and duplicate collections. Thorough overhauling of the meteorite collections was ably undertaken by Dr. Coulson during the year.

19. Presentations of collections of rocks and minerals were made to the following institutions during the year:—

1. Victoria College, Lashkar, Gwalior.
2. St. John's Diocesan Girls School, Calcutta.
3. Christ Church High School, Jubbulpur.
4. Midnapore Collegiate School, Midnapore.
5. University College of Science and Technology, Calcutta.
6. St. Barnabas H. E. School, Kidderpore, Calcutta.
7. Haranath Free Pathsala, Cossipore, Calcutta.
8. D. M. College, Moga, Punjab.
9. Talagang Government High School, Talagang, Punjab.
10. Wynson Mission School, Mussoorie.
11. Presidency College, Madras.
12. Leeds Modern School, Leeds, England.

Twelve collections as compared with an average of eleven during the past five years.

20. The following special presentations were made:—

1. A collection of quartzites to W. J. Watson, Esq., Gaya.
2. A collection of charnockite, kodurite, khondalite, gondite and "vredenburgite" to the Director, Geological Survey of Finland.
3. Crystals of quartz to Professor S. N. Bose, University of Dacca.
4. Columbite and ilmenite to W. H. Heard White, Esq., Shwemyo, Yamethin District, Burma.
5. Coal samples to Dr. J. C. Ghosh, Professor of Chemistry, University of Dacca.
6. A collection of charnockite, kodurite, khondalite, gondite, Deccan trap and older metamorphic rocks to the Director, Institut für Mineralogie und Petrographie der Universität, Leipzig.
7. A collection of Indian rocks and minerals to the Director, Free Public Museum, City of Liverpool, England.
8. Vanadiferous titanium-iron ore to Sir Douglas Mawson, University of Adelaide, Australia.
9. Rock salts to the Chief Mining Engineer, Northern India Salt Revenue, Khewra.

10. Indian manganese ores, chromite and graphite to Professor Schumacher, Head of the Department of Geology, School of Mines, Freiberg, Germany.
11. A collection of Indian rocks and minerals to the Curator, Mineralogy and Petrology, Smithsonian Institution, Washington.
12. Micaceous hematite to the Mineral Adviser to the High Commissioner for India, England.
13. A crystal of smoky quartz to Dr. K. R. Krishnaswami, Department of General Chemistry, Indian Institute of Science, Bangalore.
14. Perpeti meteorite to Professor A. Lacroix, National Museum of Natural History, Paris.
15. A collection of seven Indian meteorites to the Director, Kyancutta Museum, South Australia.
16. Perpeti and Patwar meteorites along with five other Indian meteorites to Mons. F. W. Cassirer, Prague, Czechoslovakia.
17. Patwar meteorite to the Keeper of Minerals, British Museum (Natural History).
18. Patwar and other Indian meteorites to the Smithsonian Institution, Washington.
19. A collection of Indian rocks and minerals to the Director, Geological Survey of Great Britain.
20. A polished section of 'Coulsonite' (vanadiferous iron ore) to Prof. Dr. Paul Ramdohr, Berlin.
21. A polished section of 'Coulsonite' to Mons. F. W. Cassirer, Prague, Czechoslovakia.

Twenty-one presentations as compared with an average of ten for the past five years.

21. In addition to the usual collections of minerals and rocks made by officers during the year, the following material was also presented to the Department:—

1. Steatite from Gheoria, Mewar, from the Director-General, Archæological Survey of India.
2. A large collection of minerals from the Curator, British Museum, South Kensington, London.
3. A collection of typical German potash salts from the Deutsches Kalisyndikat, Berlin.

4. A collection of seven samples of salt from the Solikamsk Salt Mine, West Ural Region, Perm, U. S. S. R. by Dr. C. S. Fox.
5. A large collection of cataclastic rocks of Finland from the Director, Geological Survey of Finland.
6. Bore-hole core showing the junction of the Talchir and metamorphic rocks from the Argada Colliery, by the Chief Engineer, B. N. Ry.
7. A large collection of crushed rocks from the Geological Survey of Great Britain.
8. A crushed vein rock from zinc mine, Tennessee, U. S. A. from the Smithsonian Institution, Washington.
9. A large collection of rocks from Tibet by Captain F. Kingdon Ward.
10. A large collection of rocks from Tibet by Messrs. R. Kaulback and N. J. F. Hanbury Tracy.
11. A large collection of rocks from the Institut für Mineralogie und Petrographie der Universität, Leipzig.
12. A collection of crushed rocks from the Director du Service de la Carte Geologique de la France, Paris.

22. During the year under report, the following meteorites were presented to the Department :—

1. Two specimens of tektites by Professor A. Lacroix of the National Museum of Natural History, Paris.
2. A series of Henbury meteorites by the Director, Kyancutta Museum, South Australia.
3. Hugoton meteorite by Mons. F. W. Cassirer, Prague.
4. Beardsley meteorite by Mons. F. W. Cassirer, Prague.
5. Gladstone meteorite by Mons. F. W. Cassirer, Prague.
6. Pasamonte meteorite by Mons. F. W. Cassirer, Prague.
7. Sioux County meteorite by Mons. F. W. Cassirer, Prague.
8. Farley meteorite by the British Museum.
9. Lake Labyrinth meteorite by the British Museum.
10. Springwater meteorite by the British Museum.
11. Narraburra Creek meteorite by the British Museum.
12. Wabar meteorite by the British Museum.
13. Tamentit meteorite by Professor A. Lacroix.
14. Anthony meteorite by U. S. National Museum.
15. Moore County meteorite by U. S. National Museum.

16. Lake Okeechobee meteorite by U. S. National Museum.
17. Harrisonville meteorite by U. S. National Museum.
18. Fisher meteorite by U. S. National Museum.
19. Colby meteorite by U. S. National Museum.
20. Roy meteorite by U. S. National Museum.
21. Tulia meteorite by U. S. National Museum.
22. Cumberland Falls meteorite by U. S. National Museum.
23. Canyon City meteorite by U. S. National Museum.
24. Coye Norte meteorite by U. S. National Museum.
25. New Leipzig meteorite by U. S. National Museum.
26. Osseo meteorite by U. S. National Museum.
27. Puripica meteorite by U. S. National Museum.
28. San Angelo meteorite by U. S. National Museum.
29. Santa Luzia meteorite by U. S. National Museum.

PETROLOGY.

Kashmir.

23. Whilst working in the Pir Panjal in the Baramula district of Kashmir from May to August, 1937, Dr. A. L. Coulson collected a specimen (51/475) of typical Panjal trap from a quarter of a mile south of Arian Nagian (34° 4′ : 74° 20′), west of Gulmarg, which was analysed by Dr. R. K. Dutta Roy. This epidotised and serpentinised rock had the unusually low silica percentage of 43·30 and was thus considerably more basic than the Panjal trap is generally thought to be. Dr. Coulson accordingly obtained from Mr. D. N. Wadia another typical specimen of Panjal trap (46/983) from between Furwater and Kulmarg in the Pir Panjal (sheet 43 K/10) which was also analysed by Dr. Dutta Roy. This specimen was slightly less basic and its silica percentage was 48·80; it is an epidotised, zoisitised and tremolitised Panjal trap.

Dr. Coulson has noted that besides these very basic and basic traps, acidic rocks occur higher in the Panjal trap suite, which are best described as devritified and otherwise altered toscanites and acid tuffs. Thus a specimen (51/468) from one mile N. N. W. of the Hotel at Gulmarg gave 71·09 per cent. of silica when analysed by Mr. P. C. Roy. A full petrological study of the various rock types present in the Panjal trap will be made when Dr. Coulson completes his field work in a future field season.

Yet another interesting rock type noted by Dr. Coulson was a hypersthene-dolerite (51/546) in the Ferozpur Nala threequarters of a mile south of Tangmarg (34° 3′ : 74° 25′), at the foot of the Gulmarg hill station. This dolerite is far fresher than the rocks of the Panjal trap, which are generally so epidotised and tremolitised that much of the original structure is lost. The hypersthene dolerite is taken by Dr. Coulson to be the sole representative so far found in his area of a younger (probably Tertiary) igneous suite. It will be remembered that the age of the Panjal trap is taken as ranging from Middle Carboniferous to Upper Trias or even younger (see C. S. Middlemiss, *Pal. Ind.*, N. S., XII, pp. 12-15, (1928)).

The interesting, very decomposed biotite-granite showing graphic structure, which crops out near Tangmarg, is definitely later in age than the Panjal trap.

PALAEONTOLOGY.

24. Dr. M. R. Sahni continued to act as Palæontologist throughout the year. Mr. N. K. N. Aiyengar, Field Collector, assisted the Palæontologist during the year in the reorganisation of the Siwalik gallery and in routine work. Mr. Dasarathi Gupta, Museum Assistant, helped the Palæontologist throughout the year in routine work. Mr. P. N. Mukerjee, Assistant Geologist, and Mr. M. S. Venkatram, Field Collector, also assisted the Palæontologist towards the end of the year, in Museum reorganisation.

Considerable progress has been made during the year under review in the rearrangement of the fossil galleries of the Indian Museum. These changes have been carried out particularly with a view to enhancing popular interest in these galleries and at the same time to add to their scientific value.

Rearrangement. Pictorial restorations.

Several of the larger vertebrates which, owing to exigencies of space, were formerly housed in the invertebrate section, have now been placed in the Siwalik vertebrate gallery. Suitable labels, describing in popular language the more interesting features of some of these forms, have been prepared by the Palæontologist. Restoration drawings of some of the more interesting genera have also been executed under his direction and are now on display. Notable amongst these are the serial wash drawings of certain proboscideans and the Equidae, illustrating various stages in their evolutionary history.

In the invertebrate gallery the work of renovating the show cases and replacing the old labels with new and up-to-date labels has been taken in hand.

Descriptive labels in the Indian languages.

An important new feature is the preparation and display of descriptive labels in the Indian languages -Hindi, Bengali and Urdu, to make the exhibits easily understandable to the lay public. A general account of the exhibits in the Siwalik gallery, dealing with their history, origin and migration, has been prepared by the palaeontologist in English. This and its translations into the Indian languages may be seen at the southern entrance of the gallery.

25. During 1937, the following memoirs were published in the *Palaeontologia Indica* :—

(1) J. A. Douglas: 'A Permo-Carboniferous Fauna from South West Persia (Iran)', Memoir No. 6, Vol. XXII of the New Series.

(2) Helen M. Muir-Wood; 'The Mesozoic Brachiopoda of the Attock District', Memoir No. 6, Vol. XX of the New Series.

(3) L. M. Davies and E. S. Pinfold; 'The Eocene Beds of the Punjab Salt Range', Memoir No. 1. Vol. XXIV of the New Series.

(4) W. B. R. King: 'Cambrian Trilobites from Iran (Persia)', Memoir No. 5. Vol. XXII of the New Series.

The following papers of palaeontological interest have appeared in the *Records* :—

(1) B. Prashad: 'Some Freshwater and Land Fossil Molluscs from near Ghorband, Afghanistan.' (Vol. 72, Pt. 1.)

(2) M. R. Sahni: 'Discovery of *Orbitolina*-bearing rocks in Burma with a description of *Orbitolina birmanica* sp. nov.' (Vol. 71, Pt. 4.)

(3) B. Sahni: 'A Mesozoic coniferous wood (*Mesembrioxylon shanense* sp. nov., from the Southern Shan States of Burma.' (Vol. 71, Pt. 4.)

(4) S. R. Narayana Rao and K. Sripada Rao: 'Some Foraminifera from the Intertrappean beds near Rajahmundry.' (Vol. 71, Pt. 4.)

(5) S. R. Narayana Rao and K. Sripada Rao: '*Holosporella* cf. *H. siamensis* Pia, from the Rajahmundry limestones.' (Vol. 71, Pt. 4.)

(6) S. L. Hora: 'On a Shark Tooth from the Lower Eocene.' (Vol. 72, Pt. 2.)

(7) S. L. Hora: 'On Fossil Fish-Remains from the Karewas of Kashmir.' (Vol. 72, Pt. 2.)

(8) S. L. Hora: 'Fossil Fish-Remains from the Saline Series of North-Western India.' (Vol. 72, Pt. 2.)

(9) W. Gothan and B. Sahni: 'Fossil Plants from the Po series of Spiti (N. W. Himalayas).' (Vol. 72, Pt. 2.)

26. The following paper of palaeontological interest is in the press and is expected to be published in 1938:—

Palaeontologia Indica.

(1) L. F. Spath: 'Cephalopoda of the Neocomian Belemnite Beds of the Salt Range.' Memoir No. 1. Vol. XXV of the New Series.

Vertebrates.

27. Prof. Baron von Huene of Tübingen has completed the examination of the reptilian fossils collected by Mr. N. K. N. Aiyengar from Tiki and Maleri and has submitted a paper on these fossils for publication. He has been able to record the occurrence of fourteen different forms of Tetrapoda, and to establish their relationships, though names could be given only to five of these.

The examination of the collection of primate fossils made by the Yale-Cambridge Expedition from the Siwalik rocks has been completed by Dr. W. K. Gregory, Research Associate in Palaeontology American Museum of Natural History, New York. Among the specimens identified are *Sivapithecus sivalensis* (Lyd.), *Sivapithecus indicus* Pilg. *Sugrivapithecus salmontanus* Lewis, *Sugrivapithecus gregoryi* Lewis, *Brahmapithecus punjabicus* (Pilg.) and *Ramapithecus* cf. *brevirostris* Lewis. It is expected that an account of the entire collection of primates will be published shortly.

Two specimens of sharks' teeth, collected by Mr. E. R. Gee from the Salt Range, were sent to Dr. S. L. Hora of the Zoological Survey for examination and report. His paper on these has appeared in *Records, Geological Survey of India*, 72, Pt. 2.

Specimens of fossil fish collected by Mr. E. R. Gee from the Salt Range and by Dr. H. de Terra from the Karewas of Kashmir, were submitted to Dr. S. L. Hora, for examination. His results are incorporated in two papers published in *Records, Geological Survey of India*, 72, Pt. 2.

Invertebrates.

28. Dr. M. R. Sahni has been engaged in the investigation of various fossil collections made by officers during the course of their survey work.

Notable amongst these is the collection of Mesozoic brachiopoda brought by Dr. A. L. Coulson from the Bannu district. The fossils are referred to two horizons; of these the lower yielded rhynchonellids and is assigned to the Callovian, corresponding to a part of the Namyau series of the Shan States of Burma. The upper, containing terebratellids and terebratulids, is separated from the Callovian horizon by a thick arenaceous series containing unidentifiable fossils, and is probably Oxfordian or younger in age. Amongst the new species described are *Ornithella coulsoni, O. indica, O. depressa, O. ovalis. O. paralagenalis, Kingena punjabica,* '*Terebratula*' *bannuensis, Rhynchonella* (? *Daghanirhynchia*) *coulsoni* and *R.* (? *Daghanirhynchia*) *pezuensis*. A preliminary notice of a paper by Dr. Sahni on this fauna has already appeared. (*Proc. Twenty-fifth Ind. Sci. Congr.* Part 3, Abstr. p. 116, 1938.)

A small but valuable collection of fossils has been brought by Mr. J. B. Auden from the Karakorum. According to Dr. M. R. Sahni three different horizons are represented. Amongst the species provisionally identified by him are *Martinia* sp. nov., related to *M. dispar* Reed from the Anthracolithic of the Shan States, *Fusulina* (*sensu lato*) and Productids, (Permo-Carboniferous); *Megalodon* sp. (photograph only), (Rhaetic); ?*Ptyctothyris* sp. nov. and *Mytilus* (*Modiolus*) sp. nov., allied to *M.* (*Modiolus*) *imbricatus* J. Sow., which is also known from the Callovian (Jurassic) of Somaliland (*vide* Cox, L. R., The Mesozoic Palaeontology of British Somaliland, Pl. XVI, fig. 3, 1935).

Further progress has been made in the identification of the Lower Triassic ammonites from Na-hkam (Northern Shan States) and a provisional note by Dr. M. R. Sahni has been published. (*Proc. Twenty-fifth Ind. Sci. Congr.* Part 3, Abstr. p. 114, 1938.) The

examination of the gastropods, lamellibranchs and annelid remains in this collection has also been taken in hand.

Dr. M. R. Sahni has devoted some time to the identification of the Devonian faunas collected by him from Me-so, Taungtek and the intervening area, Southern Shan States. Amongst the fossils found are *Spirifer* (*Reticularia*) *curvatus* Schloth., *Sp.* (*Reticularia*) *aviceps* Kays., *Cyrtina heteroclyta* Defrance, *Orthis* (*Schizophoria*) *striatula* Schloth., *Spirifer speciosus* Schloth. var. *mesoensis* nov. *Atrypa reticularis* Linn., *Leptæna rhomboidalis* Wilck., *Calymene* cf. *malaungkaensis* Mansuy. Some of the new species identified are *Rhynchonella thannooensis*, *Platyceras kachinensis*, *Pleurotomaria lihsawensis* and ?*Meristella palaungensis*. Dr. Sahni's preliminary note on this fauna appears in *Proc. Twenty-fifth Ind. Sci. Congr.* Part 3, Abstr. pp. 114-115, 1938.

The large oysters collected by Dr. C. S. Fox from the western side of the Shorbaly anticline, Afghanistan, have now been examined and identified by Dr. M. R. Sahni as *Exogyra* cf. *ponderosa*, Rœmer. This species is widely distributed in the Cenomanian. The containing beds are therefore of Cenomanian (Upper Cretaceous) age.

Certain specimens received from the Locust Research Entomologist to the Imperial Council of Agricultural Research (through the Director, Zoological Survey of India) were examined by Dr. M. R. Sahni. The material collected from Pasni in Baluchistan was found to contain foraminifera, mostly referable to the genus *Rotalia*. Only recent species of the genus appear to be represented in this material. The fossil specimens from Jaisalmer State were identified by Dr. Sahni as *Assilina granulosa* D'Arch. and its megalospheric form *A. leymerie* D'Arch. and Haime, referable to the Laki stage of the Eocene.

An enlarged diagrammatic sketch of pore-pairs of the type of *Micropedina spheroides* Stol. was prepared by Dr. M. R. Sahni and sent to Dr. Th. Mortensen, University Zoological Museum, Copenhagen, who is writing a monograph on the echinoids.

Dr. L. F. Spath, who examined Dr. Coulson's collection of belemnites from the Nai Kach, Danawat and Haidari Kach stages of Waziristan, is of the opinion that the former two are of Neocomian age and the latter may be a little higher in the Lower Cretaceous.

The ammonites and belemnites collected by Dr. A. L. Coulson from near Pezu, Bannu district, N.-W. Frontier Province were also sent to Dr. L. F. Spath for examination. He is of the opinion that

the former are Criocerates similar to those from the *Trigonia schwarzi* beds of Tanganyika. Their age is Neocomian but higher than of the Neocomian of the Salt Range, and probably Hauterivian. The belemnites are not distinguishable from those of the previous Waziristan collections of Lower Cretaceous age.

Plants.

29. The small collections of fossil plants from the Janjal plant series of Waziristan made by Dr. A. L. Coulson and Capt. Murray Stuart were sent to Prof. B. Sahni for examination. According to Prof. Sahni, Dr. Coulson's algal specimens consist mostly of indeterminable fragments. Dr. Stuart's collection contains algal impressions, which throw no light on the age of the beds. These algal remains are important in view of the fact that hardly any fucoid remains have so far been described or figured from India, but unfortunately they have not so far proved to be of stratigraphical value.

Under the supervision of Prof. B. Sahni, Mr. R. V. Sitholey has written a brief report on Dr. Fox's collection of fossil plants from Afghan Turkestan. According to this report most of the specimens in this collection are either identical with, or closely allied to, species described by Prof. A. C. Seward (*Pal. Ind.* N. S. Vol. IV, Mem. No. 4, 1912) from Afghanistan. (*Proc. Twenty-fifth Ind. Sci. Congr.* Part 3, Abstr. p. 151, 1938.)

Mr. A. R. Rao, who is working under the direction of Prof. B. Sahni on the plant remains collected by Mr. G. V. Hobson from Nipania in the Rajmahal Hills, reports the occurrence of two new species, (1) *Nipaniostrobus Sahnii* gen. et sp. nov. and (2) *Masculostrobus rajmahalensis* sp. nov., in this collection. (*Proc. Twenty-fifth Ind. Sci. Congr.* Part 3, Abstr. pp. 151-152, 1938.)

Donations.

30. During the year under review, presentations and loans of fossils or casts were made to the following persons or institutions :—

Osmania University College, Biology Department.—A small collection of vertebrate and invertebrate fossils.

Visva Bharati, Santiniketan.—A collection of vertebrate, invertebrate and plant fossil specimens from different geological horizons.

Peabody Museum of Natural History, Yale University.—13 casts of Indian fossil primates.

Director, City of Liverpool Free Public Museum, Liverpool.—A small collection of invertebrate fossil specimens (by exchange).

Sir Parashurambhau College, Poona.—A small collection of vertebrate, invertebrate and plant fossil specimens.

Christ Church Girls' High School, Jubbulpore.—A small collection of vertebrate, invertebrate and plant fossil specimens.

Director, Mining and Geological Survey Department, Netherlands Indies.—A specimen of *Lepidocyclina* limestone (by exchange.)

Robert L. Rist., Esq., Department of Palæontology, University of California, Berkeley, California. Two specimens of *Aucella parva* Stol. (on loan). Two specimens of *A. blanfordiana* Stol. and one of *A. spitiensis* Holdh. (by exchange).

Prof. B. Sahni, University of Lucknow, Lucknow.—A natural size photograph of *Protocyathea trichinopoliensis* Feist.

The Botanical Society of Bengal, Calcutta.—18 plant fossil specimens from the Gondwanas and Tertiaries of India was given on loan for exhibition on the occasion of their first Annual General Meeting.

Indian Botanical Society.—A collection of Indian plant fossil specimens was sent on loan for exhibition at the Annual Meeting of the Society.

Siemen Wm. Muller, Esq., Associate Professor, Stanford University, California. One specimen each of *Fragum praecurrens* Stol., *Cardium (Trachycardium) incomptem*, and three of *Cardium (Trachycardium) exulans* in exchange of ammonite specimens received from him.

31. In addition to those previously mentioned, fossils were received either by presentation or exchange from the following:—

Yale-Cambridge Expedition (through Dr. S. L. Hora, Zoological Survey of India).—Some fish remains from the Karewas of Kashmir.

A. N. Kashyap, Esq., Thomason College, Roorkee.—Six fossiliferous blocks collected from Waziristan.

M. Spender, Esq., Karakoram Expedition.—Some molluscan and coral fossils collected from Wesm valley.

Director, Mining and Geological Survey Department, Netherlands Indies.—A specimen of Atjeh limestone containing *Eulepidina* and *Spiroclypeus*.

STRATIGRAPHY.

32. In April I visited Bikaner City to advise on a deep boring for water which had gone down over 2,000 feet, and also examined the quarries at Dulmera, 42 miles N. E. of Bikaner City, from which the handsome building-stone so extensively and effectively used in the city is taken. The deep bore runs into similar sandstones at 240 feet, but they are not reached in the workings of the Palana colliery, about 300 feet in depth, which are situated 14 miles south of Bikaner and are in Eocene rocks.

Vindhyans, Bikaner.

The sandstones at Dulmera are horizontal, hard, dark red-brown and fawn in colour, often blotched, streaked and spotted in these two colours and are in massive beds, often false-bedded. They resemble the supposed Vindhyan sandstones of Jodhpur and the Upper Bhander sandstone of the Vindhyan plateau.

Another small outcrop, as boulders, occurs immediately east of the railway line at mile 81 on the railway line which runs north-east from Bikaner City, 2 miles south of Dhirera railway station. This is a red sandstone cemented by calcite, with a number of oolitic grains amongst the subangular quartz and felspar grains. Heavy minerals are abundant, particularly tourmaline and garnet. 48·1 *per cent.* of this rock is soluble in hydrochloric acid, and a partial analysis gives $F_2O_3+Al_2O_3$, 0·90 *per cent.*, CaO, 18·77 *per cent.* and MgO, 2·16 *per cent.* It is probably also Vindhyan.

The Eocene rocks are concealed by about a hundred feet of alluvium at Palana, the coal having been accidentally struck in sinking a well, but to the west they crop out near Gajner and extend as a tract of smooth, bare, gently rolling country, past Madh and Kolayat and ending near Bithnok. They comprise a great variety of sediments:—soft, white, sugary sandstones, tinged with pink and red, purple quartzites, surprisingly hard for Tertiary rocks, layers of ironstone, which strew their hard debris widely over the country, fuller's earth (*Multani mitti*) with well-preserved marine lamellibranchs, white nummulitic limestone, and thin bands of lignite.

Eocene, Bikaner.

33. During the year Dr. Dunn had occasion to visit Gua, Singhbhum, and examined certain of the conglomerates which are now better exposed than during the course of Mr. H. C. Jones' survey. It is clear that, at Jiling Buru, Gua, the conglomerate, which underlies shales and rests on cherty and other quartzites, marks an unconformity. Whether the conglomerate here is to be correlated with others in this vicinity in South Singhbhum, Keonjhar and adjacent States is not as yet certain, but if so, it raises the question of a wide-spread unconformity occurring within the area of the Iron-ore series rocks. There is also, now, the strong possibility that the banded hematite-quartzites, iron-ores and related phyllitic shales are really of the same age as the group known as the Older Metamorphics. If this is so, the stratigraphical sequence becomes simplified and is in close agreement with the clearly divided stratigraphy of Northern Singhbhum and Dhalbhum; the conglomerates become equivalent to the Dhanjori conglomerates of the latter area.

Conglomerates. Singhbhum.

It is hoped that the continuation of Mr. Jones' and Dr. Krishnan's work in Keonjhar State may clear up some of these points, and a re-examination of a number of the conglomerate outcrops is also indicated as desirable.

EARTHQUAKES.

34. During the year 1937 reports of 82 perceptible earthquake shocks felt by persons at rest were reported from various parts of India. With the exception of the rather severe shock of 14th November, which originated in the Hindu Kush region and affected a considerable tract of north-west India, the rest of the shocks were of slight intensity, unattended with any damage to buildings or persons -

	Shocks.
Burma	28
North-eastern India (including Sikkim, Nepal and Tibet)	31
North-western India (including Kashmir, Chitral and Baluchistan)	21
Peninsular India	2

The epicentre of the shock of 14th November 1937 has been located in the Hindu Kush mountains, north-west of Drosh, in Chitral. This has been deduced from observers' reports and from seismographic records available from the Meteorological Observatories

at Bombay, Agra, Calcutta and Kodaikanal. This shock was felt at such distant places as Kabul, Dehra Dun, Simla, Multan, Dera Ismail Khan and Roorkee.

The frequency of aftershocks of the Quetta earthquake of May 1935 appears to have considerably diminished, but several sharp shocks were felt during the year in the Assam seismic area, of which the shocks of 16th January at about 18·45 hours and of 21st March at 21·45 hours I. S. T. deserve mention.

METEORITES.

35. Mr. J. B. Auden was informed by the Tahsildar of Skardu, in Kashmir, that a meteorite fell at or near Arundu, in the north-west corner of sheet 43 M, in September, 1936.

In the Calcutta edition of the *Statesman* of the 12th November, 1937, it was reported that a number of large stones had fallen from the sky and had crushed to death two men and a woman near their hut near Jhansi in the United Provinces. The phenomenon was supposed to have occurred in a storm that was preceded by rumbling noises and a blinding light which shot across the sky. Reference to the District Magistrate of Jhansi and the Political Agent, Bundelkhand Agency elicited the information that no fall of meteorites had been reported in the district of Jhansi, or in Datia and Orchha States.

There seems little doubt that a meteorite fell near Mabwe-Khoywa village in the Karenni State of Kyetbogyi, about 120 miles east of Toungoo in Burma at about 10·45 P.M. on the 17th September, 1937. A Karen cultivator, Htisalay, while sleeping at his house, heard a noise like the explosion of a cannon in the sky and saw 'a brilliant ball of fire fall through the roof at the back of his house'. Villagers who saw the occurrence were awestruck. Some went to Htisalay's house and extinguished a fire that had been started. Next day Htisalay is said to have found a meteorite in a deep hole, and this has since entered the possession of Mr. Thompson Durmay of Toungoo. It is said to weigh about 4·9 lbs. So far it has not been examined by this Department. However, Mr. Durmay sent for examination and return a small specimen of another so-called meteorite which was supposed to have been found by Saw Derthamoo of Lapache village, Karenni State. This proved to be a schistose granite.

ECONOMIC ENQUIRIES.

Bauxite.

Jashpur State, Eastern States Agency.

36. Primary laterite resulting from the alteration of the Deccan trap *in situ* is found extensively in north-west Jashpur and in the Khuria highlands, forming cappings on the flat-topped hills locally known as *pats*. These laterite cappings locally contain segregations of bauxite. In the course of his work in Jashpur State, Dr. Dey found two areas of laterite where the segregations of bauxite are rich enough to attract attention. One is located on the *pat* north-west of Patia (22° 58′ : 84° 1′). Here bauxite occurs as scattered blocks and segregated patches in the laterite and is found all along the *pat* in its northward extension. There is also some detrital bauxite west of the village. Owing to its mode of occurrence it is difficult to estimate the total quantity of ore available near Patia, but Dr. Dey considers that there would no difficulty in obtaining 25,000 tons, or possibly much more, from this area. An analysis of this bauxite shows:—

SiO_2	1·27
Al_2O_3	58·64
Fe_2O_3	3·16
TiO_2	12·12
CaO	0·16
MgO	0·18
Alkalies	0·12
Loss on ignition	24·12
	99·77

The other area lies immediately to the south-west of Daunapat (23° 1′ : 84° 5′), at an elevation of about 3,234 ft. above sea-level. Here the material is grey and pisolitic. It is of excellent quality (*see* analysis below) and might repay exploitation when facilities for transport are available in this area—

SiO_2	1·01
Al_2O_3	59·91
Fe_2O_3	2·12
TiO_2	12·74
CaO	0·21
MgO	0·09
Alkalies	0·11
Loss on ignition	23·72
	99·91

At present both Patia and Daunapat are at prohibitive distances from the nearest railway station, Lohardaga.

Building Materials.

General enquiries.

37. A number of enquiries were received regarding building materials, particularly with reference to the cement industry. Summarised reports on the various limestone, clay, gypsum and coal occurrences of India were, in reply, issued by the Department.

Limestone, Khasi and Jaintia Hills, Assam.

38. Mr. A. M. N. Ghosh visited Shillong about the middle of January to advise the Deputy Commissioner, Khasi and Jaintia Hills, on the limestone deposits of these hills between Therriaghat (25° 11′ : 91° 46′) and Shella (25° 11′ : 91° 38′).

Limestone and sandstone, South Waziristan.

39. Dr. A. L. Coulson notes that there are large supplies of limestone in Waziristan. However, this is true of most of the North-West Frontier Province. The Shahur Tangi (Pab) sandstones could be quarried for use as a building stone but their variable hardness, texture and composition would necessitate careful selection of material being made.

Marble, Mardan district and Swat, N.-W. F. P.

40. During his survey of the Mardan district of the North-West Frontier Province, Dr. A. L. Coulson thoroughly examined the marble and dolomite deposits of Ghundai Tarako, a hill forming part of the boundary between the Swabi tahsil of the Mardan district and the Buner tract of Swat. The results of Dr. Coulson's work have been incorporated in a paper published in Part 2 of Volume 72 of the Records of the Geological Survey of India; pp. 227-234, (1937). He concludes that perhaps the largest deposits of pure white statuary marble in the Frontier Province will be found in the Gundai Tarako, but adds that careful selection of sites for development should be made, taking into consideration the type of stone required. Probably the best sites for development will be found in the neighbourhood of the main peak of the ridge.

Dr. Coulson's paper contains numerous analyses of samples from different parts of the ridge and the excellent quality of the stone available is well shown.

41. Mr. P. C. Das Hazra reports that on account of the lack of beds of limestone in Udhampur, the limestone pebbles from the Jhajjar Khad and Duddar Nala are burnt in large quantities to produce lime for mortar making. He was informed that pebbles of small sizes, from 0·2—0·4 inches in diameter, are sent in large quantities to Lahore and Amritsar for use in mosaic flooring.

Limestone, Udhampur district, Kashmir and Jammu State.

42. Mr. H. M. Lahiri reports the occurrence of crystalline limestone of Eocene (Subathu) age at Malla (30° 46′ : 76° 59′) in the Patiala State, about six miles to the south-east of Kalka. The limestone is carried to Chandigarh on the Ambala-Kalka railway where it is burnt into lime.

Limestone, Patiala State, Punjab.

43. At Zibingyi (21° 53′ : 96° 19′) in the Mandalay district, Plateau Limestone is quarried for lime burning. The limestone is burnt in primitive kilns, local firewood being used as fuel. White to slightly creamy lime is the final product.

Limestone, Mandalay district, Burma.

44. Mr. Lahiri reports that the Nahan sandstone of the hills near the water-pumping station at Kalka is used for making stone mortars (*i.e.*, vessels in which drugs, spices, etc., are pounded with a pestle).

Sandstone Ambala district, Punjab.

45. Mr. P. C. Das Hazra reports that the Murree sandstones in Udhampur district are extensively used as building stones. As the sandstones have low porosity, fairly good crushing strength and resist corrosion well, they are also used locally in constructing bridges.

Sandstone, Udhampur district, Kashmir and Jammu State.

46. Mr. Das Hazra notes the that quartzite boulders of the Upper Siwaliks and Sub-Recent deposits are exclusively used in constructing roads. The only binding material available is the calcareous Murree shales and clays.

Road metal, Udhampur district, Kashmir and Jammu State.

47. Metamorphosed calcareous sediments consisting of diopside-granulites and a little of the associated granite are largely quarried for road-metal about one mile north-east of Belin (21° 40′ : 96° 8′), Kyaukse district. The diopside-granulites are fine to medium-grained in texture, tough and very suitable for use as road-metal.

Road-metal, Kyaukse district, Burma.

48. In the hill east of Payangazu station (20° 45′ : 96° 15′), Meiktila district, fine-grained granite-gneiss is quarried for use as

Road-metal, Meiktila district, Burma.

road-metal and railway ballast. The rock is fairly compact and is sometimes associated with quartz-porphyry.

North-east of Pyinyaung (20° 49′ : 96° 26′) in the Meiktila district near milestone 32 on the Thazi-Kalaw road, Plateau Limestones are quarried for local use as road-metal. These rocks are grey in colour, fine-grained in texture, generally hard and compact and without much brecciation.

Granite, Meiktila district, Burma.

49. Mr. A. B. Dutt records that granites are largely used in the construction of piers of railway bridges on the Southern Shan States branch of the Burma Railways, especially near Pyinyaung station (20° 47′ : 96° 26′), Meiktila district. These granites are generally of the biotite-hornblende type, are fairly coarse-grained and have no appreciable gneissic structure.

Calcareous slate slabs, Kyaukse district, Burma.

50. Calcareous slates are quarried at Patta (21° 36′ : 96° 9′), about one and a half miles south-east of Kyaukse (21° 37′ : 96° 8′) Kyaukse district; they dip north at 20° and are entirely used in the Kyaukse sub-division for flooring purposes.

Clays.

Clays, Drug district, Central Provinces.

51. Occurrences of white clay have been occasionally recorded in the Sanjari tahsil of Drug district. The most noteworthy of these occur east of Hithapathar (20° 40′ : 80° 53′). The rock is free from gritty matter and is fairly plastic. Fusibility is below 1,400°C.; the brick on heating up to 1,400°C. assumes a uniform, bright porcellanic appearance without losing its shape. The clay may be usefully exploited for ceramic purposes.

Alteration and weathering of the felsitic rock of Drug has occasionally resulted in soft kaolinic matter. Often this is fairly free from grit and when kneaded with water forms a plastic mass, with fusibility just below 1,400°C. The heated brick (1,400°) suffers contraction and becomes uniformly glassy without losing shape or developing cracks. The colour of the unburnt brick is dull white, while that of the burnt brick is dark greenish grey. Noteworthy occurrences have been recorded in the river basin between Jungera Kalan (20° 42′ : 80° 58′) and Bhandaritola (20° 42′ : 80° 59′) in the Sanjari tahsil.

Coal.

North-West Frontier Province and Punjab boundary.

52. In May, 1936, the Director of Agriculture in the North-West Frontier Province raised the question as to whether the workings from which the coal then being won from the Punjab side of the Surghar range in the Mianwali district of the Punjab had penetrated beneath the crest of the boundary ridge to the Kohat district of the North-West Frontier Province. His Excellency the Governor of the latter Province approved the suggestion that Dr. A. L. Coulson should be deputed to investigate this matter and also advise on the possibilities of the coal of the Surghar range being worked from the Kohat side.

It was not possible for this investigation to take place in the field season 1935-36; but in the field season 1936-37, when it was found necessary for Mr. E. R. Gee to visit the salt mines at Khewra and Kalabagh, advantage was taken of this opportunity for Dr. Coulson and Mr. Gee to pay a joint visit to the Makarwal Colliery area in February, 1937.

In his report to the Government of the Frontier Province, following Mr. Gee's previous work, Dr. Coulson notes that the Makarwal coal is basal Eocene (Lower Ranikot) in age. A dark red, pisolitic hematite shale is sometimes developed at the expense of the coal and there is then a slightly irregular junction between the Cretaceous sandstones below and the sandstones of the basal Eocene Makarwal coal stage.

According to Mr. Gee, the general geological structure of the Surghar range is that of a fold-faulted anticline, the axis of which runs north and south to the east of the crest of the range. Generally the eastern limb of the anticline is either so faulted or has been so eroded away that little coal can be extracted. The western limb forms the main range and the coal seam dips at fair angles into the range. The anticline pitches south beyond Lamshiwal towards the Mitha Khatak gorge.

Dr. Coulson with Mr. Gee concluded as a result of their joint observations that none of the coal won from the Punjab side of the Surghar range had in fact been derived from workings extending into the Frontier Province. The very considerable amount of overburden that will be met as the present adits are driven further west, and the soft nature of the Tertiary coal, will make the extraction of the latter a matter for considerable mining skill. Accordingly

the hope of the Frontier Province Government that coal may be won as the present workings progress under the provincial boundary must be regarded as not likely to be realised. However, if workings are made nearer the Baroch gorge, these will not have to go so far westwards before they are under the crest, but here again the amount of overburden is very large.

Dr. Coulson and Mr. Gee concluded that it would not be practicable to extract the westward continuation of the coal that is at present being worked in the Punjab, by means of workings commencing in the Kohat district. It would be necessary, according to Mr. Gee's calculations, to sink a shaft 1,500-1,600 feet through the overlying Nummulitic rocks in order to meet this possible westward continuation of the Makarwal coal seam. Apart from this, the topographical features of the Kohat area seem to preclude such an attempt.

Dr. Coulson and Mr. Gee noted that coal does in fact crop out in the Kohat district to the north of the Baroch gorge. Mr. R. R. Simpson had previously noted a 2 feet 1 inch seam of coal and 10 inches of coaly shale, though his map[1] differs from the present one-inch sheet 38 P/1 in the position of the provincial boundary. Simpson states that this seam thins rapidly to 9 inches as it is traced northward and that near Sheikh Nikka the coal is frequently absent and never exceeds 8 inches in thickness.

In his report, however, Dr. Coulson recommends that it certainly seems worth while thoroughly testing and proving the area between the Baroch and Sheikh Nikka. The total cost of proving this area to just beyond point 2,997 feet should not exceed a few thousands of rupees. He recommends that this should be done by means of two drifts and possibly a shaft. One drift could be driven northwards along the strike from where Simpson collected his sample, this being entirely within the Frontier Province; the second could be driven almost horizontally westwards under hill 2,997 feet from the Punjab side, commencing low down in the belemnite beds. Alternatively a vertical shaft could be sunk, or a horizontal adit driven eastwards at a lower level, through the relatively soft Ranikot sandstones of the Makarwal coal stage to the west of hill 2,997 feet.

If coal be proved in this area, then it would probably be best mined by means of easterly horizontal drifts and then hauled by an aerial ropeway over the shoulder of the ridge and thence down

[1] *Rec. Geol. Surv. Ind.*, XXXI, Pt. 1, Pl. 2, (1904).

to Malla Khel. The Baroch has a perennial supply of good water and can easily be dammed—but no track lines could be laid up the gorge from Malla Khel to the coal outcrop.

Dr. Coulson noted that if an area of only 0·2 square miles could be proved, then assuming that the seam dips at 45°, that the coal has a specific gravity of 1·3 averaging 27·5 cubic feet to the ton and that half the coal can be extracted, then for every foot thickness of the seam the amount of coal that can be won is about 143,000 tons. If this were sold at a pit-head price of Rs. 6 per ton, there should be ample profit to the lessees.

Dr. Coulson also visited the Chichali Pass area to the north-east of the Baroch area with a view to ascertaining whether or not the horizon of the Makarwal coal stage passed into the Frontier Province in this region. He concluded that there was not much chance of workable coal being found in the salient of the Frontier Province south of Kurd. He adds that a contractor of Kalabagh had applied for a mining lease of the area between Kutki (32° 59′ : 71° 21′) and the Chichali Pass north of Kotki (33° 0′ : 71° 24′). His efforts prior to Dr. Coulson's visit had been chiefly concerned with the coal of the Jurassic variegated beds that occurs one mile north-west of Chapri and also in the bend of the Chichali stream south-west of Kotki. This coal occurs as a number of thin seams of very poor quality. Dr. Coulson says that the chances of coal being worked here economically may be stated as negligible. This Jurassic coal also extends into the southward salient of the Frontier Province from Kurd, but again has no economic value. The same applicant has also examined the Tertiary coal of the Makarwal stage within the Chichali Pass region, but Dr. Coulson's remarks regarding the improbability of workable coal being found below Kurd in the Frontier Province are equally applicable to the Punjab portion of the outcrop in the Chichali Pass. He also notes on the similarity of the geological structure of this portion of the Trans-Indus Salt Range to that at Makarwal (*see* also A. B. Wynne, *Mem. Geol. Surv. Ind.*, XVIII, Pt. 2. pp. 256-269, 1880). About 2½ miles north-west of Chapri, there is a good anticlinal structure developed in the Cretaceous and Ranikot sandstones. Were coal to be found in reasonable amount in the northern limb of the anticline, there should not be much trouble in working it; but the seam is thin and the coal is apparently not a workable proposition here.

53. In compliance with a request from the Director of Agriculture in the North-West Frontier Province, Dr. A. L. Coulson in April, 1937, investigated the coal deposits of the Dore river in the Hazara district of that Province. In view of the importance of finding workable coal in the Frontier Province, it was thought that though the Dore river coal deposits had been neglected in the past on account of their usual poor, though variable, quality, it might now be possible to utilise them, especially in view of modern developments of low temperature carbonisation.

Hazara district, North-West Frontier Province.

A short history of the former investigations on the Dore river coal is given in the "Coal" section of the Economic Geology Appendix to Mr. C. S. Middlemiss' memoir on the geology of Hazara and the Black Mountain (*Mem. Geol. Surv. Ind.*, XXVI, pp. 287-290, 1896). Middlemiss regarded the grey limestone underlying the coal as Eocene, which would make the coal younger than the basal Eocene (Lower Ranikot) age assigned to the coal of the Trans-Indus Salt Range at Makarwal. However, Dr. Coulson regards this grey limestone as Cretaceous and the Dore coal as homotaxial with the Salt Range coal.

After discussing the geology of the area and noting on the various outcrops of coal visited by him, Dr. Coulson was convinced that even with modern methods of low temperature carbonisation, the possibilities of the coal of the Dore river area being worked on any commercial scale may be discounted. He could not advise the expenditure on further trial drifts to supplement those made by early investigators. He considered that there is no continuity of outcrop of the coal owing to numerous faults and slippings; the quality of the coal is very variable and is usually poor; the thickness of the seam is either variable or small, or has a false appearance of value imparted to it by the presence of carbonaceous material which is little more than a shale; and finally, the coal-bearing sandstone is so kneaded up and crushed by earth-movements owing to its position between two hard limestones which have acted as crushers as to be usually impossible of being worked on a commercial scale. As a potential source of fuel for the North-West Frontier Province, the Dore river coal may be ruled out. Dr. Coulson considered that efforts should be directed towards proving the coal to the north of the Baroch in the Kohat district rather than in wasting further money on the Hazara coal.

Copper.

54. Thin films and small stringers of malachite were found by Dr. Dey in an aplite vein occurring on a hill about 1 mile south-west of Simirkacha (22° 35′ : 83° 51′). The occurrence has, however, no economic importance.

Jashpur State, Eastern States Agency.

55. Dr. A. L. Coulson notes that frequent small occurrences of malachite of mineralogical interest but no economic value occur in the Neocomian shales and at the base of the Shahur Tangi (Pab) sandstones west of Spli Toi Post (32° 20′ : 70° 0′) and in the hills south-west of Haidari Kach (32° 19′ : 69° 59′) in South Waziristan.

South Waziristan.

56. Mr. Dutt reports the occurrence of copper pyrites associated with tuffs by the side of the stream about one mile north-west of Kanse (21° 12′ : 96° 21′), Kyaukse district. This occurrence has been known for several years but as the ore is very indefinite and scanty no attempt has been made to exploit the deposit.

Kyaukse district, Burma.

57. At the request of the Madras Government Mr. Crookshank examined a deposit of copper-ore found in the course of well-sinking at Ganugupentapalli near Udaygiri in the Nellore district.

Nellore district, Madras.

On his arrival he found that the well had recently been lined with concrete, consequently he was unable to see anything of the deposit. He was, however, shown some pieces of copper pyrites by the villagers, who were under the impression that the ore was gold.

According to the villagers a rich vein of ore about one foot thick was encountered at one side of the well. It did not extend in depth, nor could it be traced laterally across the well.

A search was then made for copper-ores in the surrounding chloritic quartzites. Although these are the country rocks of the copper-ore no surface indications of copper were found in them in or around the village.

It is thought that the deposit, though rich, is of trifling size and of no economic importance. In this it resembles a number of other deposits of copper found in the Nellore district.

58. Mr. Crookshank reports traces of copper in the rocks 2 miles E. N. E. of Kottapalli (18° 21′ : 81° 18′). The occurrence is not considered to be of any economic importance.

Bastar State, Eastern States Agency.

Engineering and Allied Questions.

Elephanta Caves sculptures.

59. Elephanta is one of the small islands lying off the coast of Bombay, about 7 miles from Bombay harbour. It is composed of flows of Deccan Trap of doleritic, basaltic and andesitic composition, some of which are amygdaloidal. The rocks are weathered to varying degrees as the island is fully exposed to moisture-laden wind from the sea.

There are several caves containing sculptures of Hindu Gods and mythological figures hewn out of the solid rock. The caves and sculptures are said to date from the 6th century A.D. During the time when the island was under the occupation of the Portuguese (1534 to 1774 A.D.), the caves were in a very neglected state and the sculptures were also subjected to disfigurement at the hands of the garrison which occupied the island. The caves were cleaned up after the island came under British occupation, but it was not until 1872 that any effort was made to preserve the architectural treasures.

The main cave shows that dirt and debris must have accumulated to a height of about 4 to 4½ ft. from the floor, the walls to that height showing deep decay due to the action of accumulated salts.

In 1935, some fragments of the sculptured figures, which had developed fractures, fell off and measures had to be devised to prevent not only the further development of cracks and fractures but also the general decay of the rock surface. Mr. M. Sanaullah, Archæological Chemist with the Government of India, made an investigation and recommended certain measures to be taken. A Committee was set up by the Government with Mr. J. F. Blakiston, C.I.E., Director-General of Archæology, as Chairman, and Prof. S. S. Bhatnagar and Messrs. A Croad and S. N. Gupta as Members, and Mr. M. S. Vats as Secretary. Dr. M. S. Krishnan, Geologist of the Geological Survey of India, was deputed to advise the Committee on the geological aspects of the problem.

The Committee examined the caves and held sittings at Bombay in November, 1936. Dr. Krishnan discussed the problem of preservation with the Members of the Committee on the spot and also collected samples of the decayed rock from the floor and wall of the caves. One set of samples was analysed for soluble salts in the Geological Survey Laboratory and duplicates were handed over to the Royal Institute of Science, Bombay. Specimens of decayed

rock were also sent by the Superintendent of Archæology, Western Circle, to the Government Test House, Alipore.

Dr. Krishnan submitted a report to the Director-General of Archæology in due course, based on the results of analyses in the Geological Survey of India and the Alipore Test House. His recommendations, summarised below, have been accepted by the Committee.

The analyses of the samples collected by Dr. Krishnan revealed the presence of appreciable quantities of sulphates, chlorides and nitrates in the decayed rock. It was learnt later that the analyses made at the Royal Institute of Science showed an absence of nitrates, but this may be due to different methods of analysis.

The decay is due to the action of salts derived from wind-borne moisture from the sea, to organic matter accumulated during the years of neglect, and to decomposition of pyrites in the rock, the acid so generated acting on the minerals and producing sulphates, notably of calcium, magnesium and the alkalies. The dripping of water from cracks in the roof also plays an important part in the decay.

Dr. Krishnan has recommended the following action to be taken for the prevention of decay and the formation of cracks. The cracks in the images and sculptured parts should be cleaned free of dust and salts and cemented together with a suitable cement, the larger pieces being held together by rivets of a non-rusting alloy. The cement should be protected from atmospheric action by a coat of preservative or varnish on the surface.

For the removal of the accumulated salts on the surface, Dr. Krishnan agrees with the Archæological Chemist that the repeated application of paper pulp would be a suitable remedy where sculptured figures are concerned, and spraying by water where the walls have no figures or other ornamentation. The surface can then be dried by compressed air and preserved against future accumulation of salts by the application of a suitable varnish.

The percolation of water through the roof must also be prevented. Dr. Krishnan agrees with Mr. Croad's suggestion that the top of the roof forming the hill side should be stripped free of soil, the joints cement-grouted and the surface painted periodically with asphalt.

60. In March, 1937, at the request of the Chief Engineer, Public Works Department in the North-West Frontier Province, Dr. A. L. Coulson visited Malakand in connection with the hydro-electric scheme then under construction, to report on the nature of the geological conditions and their effect on the stability and permanence of the works.

Malakand Hydro-electric Scheme, N.-W. Frontier Province.

The water of the Upper Swat canal, which is taken from the Swat river at the canal headworks at Amandarra (34° 37′ : 71° 59′), is led through the Benton tunnel for about 2½ miles under Malakand (34° 34′ : 71° 56′) to the Mazah Khwar, the bed of which is followed for a short distance before the water is again taken into a canal for distribution to a large part of the North-West Frontier Province.

The hydro-electric scheme proposes to take some 1,000 cusecs of the 1,500-1,600 cusecs of water debouching from the Benton tunnel through another tunnel, hereinafter referred to as the power tunnel, about 2,249 feet in length, and then along an open cut with a silt trap a short distance to a concrete masonry weir supporting the tops of three pipes down which the water will fall some 250 feet to drive three turbines situated on the right-hand bank of the existing Upper Swat canal. The surplus water will flow by two concrete siphons into a pit and thence over a weir to rejoin the Upper Swat canal between the turbines and the power house by means of a natural *nala*. The water in the power tunnel will have an approximate depth of ten feet.

The scheme will generate cheap electricity which will be supplied to the North-West Frontier Province and will be an immense boon to that Province. It was hoped to complete the scheme by September, 1937, but unforeseen difficulties have hampered the work and it was doubtful if completion by that date was possible.

The power tunnel had been driven through at the time of Dr. Coulson's visit and work was then being concentrated on the open cut and on the hillside on which the pipes were to be laid and held in position.

In 1908, Sir Thomas Holland reported geologically on the character of certain rocks in the Malakand range of hills in connection with the proposal for driving the Benton tunnel, long since completed, for the water of the Upper Swat canal. Mr. G. H. Tipper also reported on parts of the range.

The conditions existing in the Benton tunnel are different from those in the nearby power tunnel. In the former, the rock is practically all muscovite-granite, but no granite crops out in the vicinity of the power tunnel. Two apophyses of granite, which have found their way along the foliation planes of the schists, may be seen on the path down from Malakand to the power tunnel.

The schists are far from constant in character and a great variety of types exists. Dr. Coulson noted hornblende-schists, calc-schists, biotite-quartz-hornblende-calc-schists, muscovite-calc-schists, muscovite-zoisite-calc-schists, etc. The assemblage contains stringers of pegmatite, usually vein-quartz, but quartz-muscovite-pegmatites, some with "books" of muscovite up to three-quarters of an inch across, occur. Dr. Coulson noted ample evidence of crumpling, buckling, slipping and faulting of strata. In the upper part of the Mazah Khwar, there seems to be a fault parallel to the line of the stream bed, with other cross-faults as one approaches the exit of the Benton tunnel. Through the power tunnel, also, all these phenomena were noted.

The foliation planes of the schists apparently agree with the planes of sedimentation of the original somewhat heterogeneous shale series that was metamorphosed into the present assemblage of schists.

In his detailed report, Dr. Coulson mentioned the liability of Malakand to earthquake shocks and stated that even if disastrous shocks were not felt, a slight shock might be sufficient to cause movement of strata already in a precarious state of equilibrium. He was also influenced by the fact that once the scheme was in operation, there can be no stopping for repairs to the channel along which the water is flowing. At present the headworks of the Upper Swat canal have been closed periodically to enable the Benton tunnel to be examined. But once the hydro-electric scheme is in operation, the only part of the Upper Swat canal that can be closed will be that portion below the power house.

The schists through which the power tunnel has been cut are easily permeable by water along their foliation planes. Consequently their fissility is largely increased when they are sodden with water. Dr. Coulson noted, however, that if the foliation were transverse to the line of the tunnel the roof and walls should normally be fairly safe provided there was no evidence of buckling and crumpling. When, on the other hand, the foliation of the schists

was parallel or nearly so, to the line of the tunnel, and the roof is consequently left unsupported for considerable distances, if water is leaking through the roof, then the condition of that cannot be regarded with equanimity, especially when there are signs of slipping or crumpling. Though it may remain in equilibrium for a long time, a slight shock may dislodge a small block of the roof, rendering probable ever larger and larger falls. Here, also, the dip of the strata is important. If the dip is to one side, the side dipping into the tunnel will have a tendency to slip into it, especially if the foliation planes are lubricated with water.

Dr. Coulson discussed the question of the safety of hillsides with varying conditions of dip, especially in reference to the open cut and the hillside from the pipe intake to the turbines below. He considered that the small amount of silt in suspension in the water during a short period each year was not likely to cause excessive erosion. He noted that as abundant water was available, small leakage losses did not matter, especially as such leakage water would normally rejoin the Upper Swat canal along the bed of the Mazah Khwar.

After describing the conditions along the length of the power tunnel in great detail, Dr. Coulson made numerous recommendations regarding lining and supporting the power tunnel and for the safety of the open channel.

Power for Hazara district, N.-W. F. P.

61. In view of the cost of extending to the Hazara district the grid system of the Malakand Hydro-electric Scheme, the late Mr. A. T. Arnall, Superintending Engineer of the Electricity Circle in the Public Works Department, North-West Frontier Province, expressed keen interest in Dr. Coulson's investigation of the coal of the Dore river (see p. 36). As Dr. Coulson discounted the economic value of the coal in question, he invited attention in his report to the hydro-electric possibilities of the perennial streams in the Hazara district. The Dore river would be rather difficult to dam at some such place as just below its junction with the Harnow river. Though the Nummulitic limestone on the right bank would offer a moderately good foundation, a fold-fault runs along the course of the stream. Damming would flood the lower part of the Harnow and would cause much expense in the provision of bridges etc., for the Abbottabad-Nathiagali road. Also the stream is very subject to spates and enormous quantities of detritus are carried down by it.

The Harnow river apparently has a perennial flow. It has a very steep gorge which should be easy to dam below Jhafar without inundating any land of value. Whether the capacity of such a dam (provided the extent of the flow of the Harnow would be sufficient to replenish the supply) would suffice to provide power for the Hazara district is a matter for the engineers concerned.

In Dr. Coulson's opinion, however, recourse could very easily be made to the more suitable stream, the Kunhar, along the course of which, no doubt, suitable alternative sites could be found for dams which would supply the whole of the Hazara district with power.

Water-supply, Baluchistan.

62. In response to a request by the Engineer-in-Chief, Army Headquarters, Dr. A. L. Coulson was deputed in December, 1936, and January, 1937, to investigate the water-supplies of certain tactically important areas in the Zhob district of Baluchistan, and also an area in the Quetta-Pishin district. Dr. Coulson's stratigraphical notes are published elsewhere in this Report (see pp. 80-83).

Pench River Hydro-electric Scheme, Nagpur district, C. P.

63. In January, 1937, Mr. W. D. West examined the site of the reservoir and dam for the Pench River (Surera) Hydro-electric Scheme. This scheme is for the generation of electrical energy for use at Nagpur, and involves the construction of a reservoir on the Pench river below Kandlai, at a point some 36 miles in a direct line N. by E. of Nagpur, on sheet 55-O/2 where it flows south through hilly country.

The dam and reservoir sites are located on folded Archæan rocks, the strike of which is parallel to the alignment of the proposed dam. These rocks, which comprise three stages of the Sausar series, namely banded granulites, calcitic marbles, and muscovite-biotite-schists, considerably veined by aplite, are disposed in the form of an anticline and syncline overturned to the N. N. E. The dam site is located on one limb of the banded granulite, which forms a prominent ridge through which the river has cut its way.

The banded granulite is a very tough rock, though considerably jointed. Mr. West, however, is of opinion that the joints will be found to be tight in depth, but suggests that preliminary excavation along the site of the dam should be undertaken to settle the point. Apart from this, the site selected for the dam may be considered to be a good one, provided certain precautions are taken.

To obtain the necessary storage, the dam at this site will require to be about 116 feet high, which will maintain a reservoir extending about six miles up the river to Kandlai, with a capacity of 3,600 million cubic feet. The site appears to be quite suitable for a reservoir, and in view of the thickly forested nature of the catchment area, silting of the reservoir is not likely to become a serious problem.

The scheme as a whole may present certain engineering difficulties, but from the geological point of view the site is considered by Mr. West to be a reasonably good one.

Tons River Hydro-electric Scheme, Rewah State, Central India.

64. In February, 1937, Mr. W. D. West was deputed to report on the geological aspects of the Tons River Hydro-electric Scheme, in the northern part of Rewah State, Central India. This part of the State is situated mainly on an elevated plateau, averaging about 1,000 feet in height. It is bounded on the south by the Kaimur range, and on the north and east by the escarpment that overlooks the plains of Allahabad and Mirzapur. The Kaimur range gives rise to a number of streams flowing northwards across the plateau, of which the most important are the Tons and Bihar rivers. On reaching the northern edge of the plateau, these streams descend abruptly to the plains by a series of waterfalls, and it is proposed to utilise this drop for the production of hydro-electric power.

The possibilities of such a scheme have long been recognised, and they have been referred to in the reports of the Hydro-electric Survey of India. Closer examination, however, has generally revealed that the conditions are not altogether ideal, and it is for this reason, no doubt, that little progress has so far been made.

The rainfall of this area averages about 42 inches a year, which must be accounted quite good. Owing, however, to the scarcity of vegetation in this part of the State, the rain, as soon as it falls, rapidly runs off the ground into the streams and rivers, and is thus quickly lost. It is for this reason that the flow of water in the Tons and Bihar rivers rapidly decreases after the monsoon, and soon falls below the volume required for the production of the minimum amount of power. The construction of a reservoir on the top of the plateau is the obvious way of controlling the flow of water, but this is made impracticable by the fact that, owing to the very level nature of the plateau, the formation of such a reservoir would flood large tracts of cultivable land, and thereby prove uneconomic on account of the compensation that would have to be paid to the large

number of villages affected. In view of these difficulties, a scheme is under consideration which makes use of the combined waters of the Tons and Bihar rivers. This involves utilizing the flow in the Tons river until about the beginning of February, thereafter supplementing it with water from the Bihar river. Even so the latter will be insufficient during the hot weather, and it will be necessary to conserve its waters by the construction of a reservoir. By thus combining the waters of the two rivers, such a reservoir would not require to be so large, and the amount of flooded land would be kept to a minimum.

The details of the scheme are as follows. It is proposed to build a storage reservoir in the upper reaches of the Bihar river about four miles south of Rewah. The waters of this reservoir, when required, will gradually be released down the Bihar, and a diversion weir in the Bihar somewhere above the Chachai Falls will divert the water across the Bihar-Tons watershed into the Tons river. A pick-up weir in the Tons, a short distance above the Tons Falls, will feed the power channel leading to the power house forebay, which will be situated about a mile and a half downstream of the falls. In this way it is calculated that a minimum flow of at least 300 cusecs can be maintained throughout the year.

The geological structure of the area is simple and consists of a very shallow syncline of Vindhyan rocks, comprising the Upper Rewa sandstone, the Ganurgarh shales, the Bhander limestone and the Lower Bhander sandstone, in ascending order. It is the Upper Rewa sandstone which forms the escarpment over which the Tons and Bihar rivers descend in waterfalls to the Gangetic plain.

The site of the dam of the proposed reservoir on the Bihar is located on the Bhander limestone. This is a massive, fine-grained limestone, which is well bedded and jointed. It is, possible, therefore, that a certain amount of leakage may occur, which must be considered from two aspects, (1) loss of water from the reservoir, (2) the safety of the dam. Regarding the first point, a certain amount of leakage will not greatly matter, since the Bhander limestone is underlain by the impervious Ganurgarh shales. And since the latter crop out in the river below Rewah City, any water that may be lost from the reservoir will be collected further downstream, and ultimately utilised.

Regarding the safety of the dam, which will only be about 40 feet high, Mr. West considers that if adequate precautions are taken to protect the floor of the reservoir immediately upstream of the dam, and if the dam be given fairly deep foundations, any possible danger to the dam should be provided against.

Mr. West also examined several sites for the diversion weir on the Bihar, and considered that the site at Simon Ghat would be suitable provided that the weir is designed with gates that would let the excess water through with little or no fall on to a protecting apron.

The site suggested for the pick-up weir in the Tons river is located on Upper Rewa sandstones, which extend most of the way across the river. The site appeared to Mr. West to be a good one, provided precautions are taken to prevent leakage by sealing up conspicuous joints in the bed of the river above the weir.

Two sites were examined for the pipe line and the power house. Mr. West considered one of these to be quite satisfactory, as the pipe line would be founded on solid rock practically the whole way down, while a convenient ledge, just above high flood level, offered a suitable site for the power house.

Tube-well irrigation in Teonthar tahsil, Rewah State, C. I.

65. While in Rewah State, Mr. West was also asked to give an opinion as to whether the subsoil strata in Teonthar tahsil, the northern tahsil of the State, are suitable for tube-well irrigation. This tahsil is situated at the foot of the *ghats*, and forms the southern edge of the Gangetic alluvial plain; and the question considered was whether there is likely to be sufficient water in the alluvium of this area to enable tube-well irrigation to be conducted in the manner adopted in the more northern part of the United Provinces.

General considerations suggest that the floor of the alluvium of the Gangetic trough slopes very gently northwards, and that the alluvium is shallow on the southern side of the trough. This view is supported by the fact that Vindhyan rocks are seen in the bed of the Tons river at Chak ghat, where the main road from Rewah to Allahabad crosses the river. There can thus be little doubt that the alluvium of the whole of this tahsil is quite thin. The possibility, therefore, of a deep reservoir of water existing in this area, suitable for extensive irrigation, is considered by Mr. West to be out of the question.

66. Mr. West also examined the dam site for the Nindeh reservoir, which it is proposed to construct on the Nindeh river, a tributary of the Karmnasa river in the southern part of the Mirzapur district. This scheme has been drawn up with a view to utilizing the energy available from the water that is let down from the Dongia reservoir for the irrigation of the Garai canal system. It has been estimated that about 130 cusecs on an average are let down for 123 days in a year. It is proposed that during the rest of the year the necessary supply of water should be obtained by building a reservoir on the Nindeh river.

Nindeh reservoir dam site, Mirzapur district, U. P.

The whole of the area under consideration is situated on the Kaimur sandstone. On account of the damage done to the rocks in front of the spillways of the Dongia reservoir during the high flood of 1936, it was considered desirable to determine whether the same weakness existed in the rocks at the proposed site for the Nindeh dam. At the Dongia reservoir the Kaimur sandstone is highly jointed, and moreover the joints are deeply weathered. In consequence, during the flood of 1936 the weathered portions of the joints were washed away and large flags of the rock were uprooted and moved bodily downstream. Examination of the rocks at Nindeh showed at once that the sandstones, although belonging to the same series, are markedly less jointed, both at the surface and in depth, and Mr. West considered that, provided the usual precautions were taken to grout any prominent joints that exist along the dam site and for a short distance above and below it, there was no objection to the site.

67. By desire of Surgeon-General Goil I visited the Darjeeling catchment area on 8th October 1937. It has been in the past a popular saying that the common intestinal troubles of Darjeeling in the monsoon were due to "mica in the water". Previous to my visit I had examined in Calcutta two samples of the Darjeeling water drawn during the monsoon, one of the water as it flowed into the storage reservoirs ("Senchal Lakes") and one as it flowed out of them towards Darjeeling. Both were entirely free from mica or kaolin, but contained an infinitesimal amount of chloritic matter, and a surprising amount of vegetable debris. Mica in any quantity would no doubt be an irritant to the intestines, while kaolin would act as the reverse. The latter is, like chalk, used in medicine, I believe, as an internal

Water-supply, Darjeeling, Bengal.

soothing agent, and it is known to be eaten in India in the form of "edible clay". Chlorite, being unctuous, soft and insoluble, would be neutral, and the quantity present is almost imperceptible.

The catchment area consists entirely of the Darjeeling gneiss, a banded rock consisting of quartz, felspar, biotite and muscovite mica, garnet, chlorite, tourmaline and apatite. Of these minerals only felspar and mica are decomposable by ordinary atmospheric agents, and as the water in the catchment area runs rapidly through it in torrential hill streams, hardly any salts can be dissolved, and, in point of fact, Darjeeling water is notably "soft".

When I visited the reservoir, water was running strongly into it, after some days of heavy rain, but the water was crystal clear though carrying much leaves and other vegetable debris, and coarse sand comprising granite, quartz, felspar and mica. Much of this is retained in a small tank provided with baffle-plates, where the supply enters the reservoir, and any left will promptly settle in the reservoir close to the inlet.

To conclude, the Darjeeling water is markedly free from mineral impurities, either solid or dissolved, but carries much floating vegetable matter after rain.

Water-supply, Belgaum cantonment, Bombay.

68. Mr. Crookshank was deputed to examine the water supply of the Belgaum cantonment on behalf of the Southern Command.

He reports that Belgaum is situated on Deccan trap flows which form here a thin skin over Dharwar schists. Between these two main formations is a variable thickness of gravel and clay which probably represent the Lameta beds of other parts of India.

The present water supply is derived from numerous wells tapping the weathered surface of the basal trap flow. It is unlikely that further wells tapping this horizon would add much to the total water supply of the area, as the existing ones probably extract the bulk of the water that soaks into the rocks of this horizon during the rainy season each year.

Mr. Crookshank recommended an experimental boring through the lowest trap flow into the gravels which separate it from the underlying Dharwars. The depth to the base of the lowest flow in the Nagzeera area is probably less than 200 feet. Water, if any, tapped by such a boring would probably be perennial, and its extraction would be unlikely to affect existing well-water supplies.

Subsequent information is to the effect that the beds between the Deccan trap basement and the schists have not yielded water in the Nagzeera boring. In the event of the boring at Nagzeera proving a failure, Mr. Crookshank considered that a larger scheme for supplying water both to the civil and the military should be investigated.

Two perennial streams exist within six miles of Belgaum—the Mogitra *nala* and the Markandeya river. The former flows over a gravel bed, but well-sections show that Dharwar schists underlie the gravel at no great depth. It is suggested that a trench be made across the *nala* bed down to the schist at some time during the hot weather, and that tests be made to see how much water passes. If the supply is adequate it would be a simple matter to bring it in to Belgaum.

Failing an adequate supply a storage reservoir would have to be constructed. This might be done at some suitable place further down the Markandeya river or in the valley of the Markandeya below the Poona-Belgaum road. In the first area the reservoir could easily be founded on the impermeable Dharwar schists and in the second on the equally sound Purana quartzites. The selection of the dam site would be mainly a matter of engineering convenience.

Water-supply, Jubbulpore, Central Provinces.

69. At the request of the military authorities Mr. H. Crookshank was sent to Jubbulpore to investigate the possibilities of finding water in the vicinity of Kerendi hill east of that city.

He reports that the geology of the Kerendi area is almost identical with that near Bara Simla where 10 very successful borings have already been sunk. He considers it certain that valuable supplies of water can be made available by drilling on the sites selected by the military near Kerendi hill. He is unable to say whether the results will be as good as those already obtained in the Bara Simla area, but he considers that they should be quite comparable. Some improvement in the yield of bore holes should be obtainable by sinking them to a greater depth than has been done so far, but whether the extra yield would justify the expense he is unable to say. The maximum possible yield would only be reached on boring through the Gondwana rocks exposed at the surface to the underlying granitic ones. The depth down to the granitic rocks is not known.

It is unlikely that the withdrawal of the amount of water required by the military will seriously reduce the underground water level in the Jubbulpore area.

70. At the instance of the Director of Agriculture, Punjab, Mr. H. M. Lahiri was asked to visit the area around Khair, (31° 12′ : 75° 55′) in the Nurpur tahsil of the Kangra district and to report on the geology and water supply possibilities thereof.

Water-supply, Nurpur tahsil, Kangra district, Punjab.

Mr. Lahiri reports that the site selected by the Agricultural Department for sinking a trial bore-hole for water lies on clays, loams and gravels of probable sub-Recent age, which occupy a large area in the valley of the Buhl Khad and its tributaries in the eastern part of sheet 43P/16. The depth of these beds at the proposed site is unknown and can be ascertained only by actual boring.

Examination of the existing wells of the area has shown that while the sub-surface water table only about one mile to the north or south-east of the proposed site is, in the winter months, quite close to the ground level, that at Khair itself is at least 50 feet below the stream bed east of the village. The depth of the valley deposits at the site is not known, but whatever it may be, from various considerations, the chief amongst which is the proximity of the place to the main water-parting and the consequent smallness of the collecting surface, the chances of obtaining a satisfactory supply of water from these beds are rather remote.

Mr. Lahiri has also considered the possibility or otherwise of obtaining artesian or sub-artesian water in the area. The synclinal structure of the Siwalik beds below the Buhl valley deposits, the porous character of the outcropping Siwalik rocks, their alternation with clay beds and the general lower level of Khair than that of the rock outcrops on either side, are apt to raise expectations of obtaining such water. But when the Siwalik beds cropping out to the south-west of Khair are followed down along their dip towards the north-east, they will probably be found at a minimum depth of 500 feet under Khair and accordingly it would be necessary to sink a bore-hole deeper than this in order to tap water from them. Also, frequently occurring boulder-beds are likely to give trouble in boring. Further, it is not known whether the Siwalik beds are as porous below the valley deposits as they are in their weathered outcrops.

Nor is it known with certainty if the clay beds seen in the outcrops continue north-eastwards under Khair. In these circumstances, Mr. Lahiri does not think it advisable to undertake any deep boring here on the chance of obtaining artesian or sub-artesian water.

Mr. Lahiri notes that while the prospects of obtaining sufficient water at Khair are poor, only about 1¼ mile to its south-east, at the junction of the Dhial ka nala and the Rahen *nadi*, shallow hand-dug wells are known to yield an inexhaustible supply throughout the year. The yield of a well situated at the junction may be increased, if desired, by running infiltration galleries up the Rahen *nadi*. This site commands a large collecting surface and the annual rainfall being fairly high (62 inches), the supply is expected to be satisfactory.

Water-supply, Jashpur State, Eastern States Agency.

71. In advising the authorities of the Jashpur State regarding the question of a well for the proposed water-works at Jashpurnagar (22° 53′: 84° 8′) Dr. Dey observes that the rocks around Jashpurnagar are mainly granitic gneisses and laterite. The rainfall, which averages about 66 inches a year at Jashpurnagar, is the most important factor in controlling the level of the ground-water. The present source of water-supply is derived from a number of wells dug in the permeable soil, subsoil and superficial laterite. Many of the wells become nearly dry towards the middle of the dry season. It is believed that these wells do not reach the zone of permanent saturation but derive their supply from a temporary saturation of the upper parts of the sub-soil in the rainy season. For permanent water-supply the wells should be sunk deep enough to reach the solid bed-rock.

It has been proposed to sink a well in the *doin* near the Power House with the hope of obtaining a supply of 35,000 gallons per day. A study of the wells shows that the under-ground water-table at Jashpurnagar is about 30-45 ft. below the surface. At these depths the wells appear to have low recuperative powers. If, therefore, the site for the new well be selected in the *doin* near the Power House, a large well sunk to a much greater depth than has hitherto been done at Jashpurnagar will be essential. If the supply is inadequate from the well, even after taking it down to the bed-rock, infiltration galleries may be driven in suitable directions, in order to increase the seepage surfaces.

The best source of supply, according to Dr. Dey, would be from a large well sunk in the bank of the tributary *nala* of the Banki *nadi*, south of Bartoli. The well would be on the low ground about 20 feet from the bank of the *nala*, above the flood-water level. The pump house would be situated on the bank of the *nala* and the reservoir tank may be constructed on the high ground of laterite further north. The well should be sunk deep enough to reach the bed-rock.

A second suitable site for a large well is the water-course E. N. E. of the *bund* near the Club House at Jashpurnagar. This water-course has perennially running water. An adequate and reliable source of water, sufficient for the present requirements of the town, would be obtained by sinking a large well down to bed-rock, on the low ground, north of the wooden bridge near the *bund*.

Glass Sands.

Dehra Dun district, U. P.

72. Mr. Auden states that glass-sand rock occurs extensively in the older Dun gravels in the neighbourhood of Dehra. At Lachmansidh (30° 15′ : 78° 5′) boulders of quartzite are broken up by hammering and sieved through a 1/20th inch mesh. These quartzite boulders rest in a sandy clay matrix and are probably derived from the Nagthat (Jaunsar) series cropping out north of the Dun. Their silica cement has been removed, presumably by the leaching effect of humic acids permeating the gravels, which are covered with *sal* forest. Similar desilicified boulders occurs on the hill west of Rajpur (seven miles north of Dehra), on Angaila hill (30° 23′ : 78° 2′) and on hill 2927 (30° 28′ : 77° 52′).

Gold.

Jashpur State, Eastern States Agency.

73. During the field season Dr. Dey demarcated the principal gold-producing area of Jashpur State. This area according to Dr. Dey lies to the south of lat. 22° 39′. It is underlain by gneissic rocks cut by innumerable veins of quartz and tourmaline-quartz rocks, and is drained by the river Ib (Eeb) and its tributaries. Sparsely disseminated gold occurs in many places but the outstanding feature of the area is the occurrence of an auriferous gravel bed under

the alluvium in the bank of the Ib and its tributaries, the Maini and the Sonajori. This gravel bed had been exploited by shafts and open cuts usually located on the banks of the rivers or at some distance from them. Evidences of old placer mining are abundant in the area. But as a considerable time has elapsed since the mines were worked, the pits have caved in and become filled up to such an extent that it was impossible to examine a section of the gravel bed. At a few points, however, where the gravel bed is exposed in the valley of the Ib, it is seen to rest on a gneissic platform at a depth of 15 to 20 ft. and to have a thickness of 1 to 1½ ft. The gravels mostly consist of well rounded pebbles of vein quartz, tourmaline-quartz rock, tourmaline, *etc.*, in a clayey matrix.

The mining was in progress during the past century but was suddenly suspended by the State sometime in the late eighties, owing, it is said, to accidents in the mines and also because of the smuggling out of the State of the metal won. At present, no digging of any kind for gold is allowed. The only gold now obtained comes from the washing of the river sands and the soil mantle on the stream banks and on the divides between the *nalas*. The experience of generations of gold-washers has enabled them to locate the spots where their operations would be most paying. Gold-washing is carried on mainly during the rainy season; at other times it is practised only casually after heavy showers. The gold thus obtained consists mostly of small flattened particles of bright yellow colour showing no tarnished or black coating. Individual particles are spongy and a few show under a powerful lens minute particles of quartz attached to them. Although the corners of a great many particles have been somewhat rounded, they do not in general appear to have been transported far from their place of origin. About 30-50 *tolas* of gold are won annually. This amount is purchased by the State in exchange for rice. The average earnings of the gold-washers are exceedingly small; they, therefore, combine this pursuit with other occupations.

From the abundance of ancient workings, it should not, however, be supposed that the placers in the State have been worked out. There are areas on the bank of the Ib which have not been exploited to any considerable extent. The placers in such areas are shallow and there would not be any special difficulties in working

them. The pay gravel may be found in depth underneath the alluvium at other places.

From the physical characters of the gold and from the distribution of the auriferous alluvium Dr. Dey is led to believe that the gold has been derived from the quartz veins which are so abundant in the area. The quartz veins have not been prospected as yet. A study of these veins appears necessary, as this would not only help to locate the probable areas in which placer deposits may be expected but they might themselves possess a gold value high enough to warrant development.

It is hoped that during the ensuing field season suitable prospecting operations will be undertaken in order to indicate the economic possibilities of these gravels. As the auriferous gravel deposit is usually shallow, the operation of prospecting by means of a number of trial pits will not be expensive. The overlying alluvium is soft and easily removable. The pits should, according to Dr. Dey, be sunk to the solid bed-rock as the underlying gneiss is known to carry gold on its decomposed surface.

Katha district and Mongmit State, Burma.

74. On the north side of the Mogok 'massif' illicit gold workings were noted by Mr. Clegg at the following places:—

(1) One mile south-east by south of Pinkan in a tributary of Maunggwe *chaung* (23° 5′ : 96° 10′).

(2) Paungsho *chaung* from the Twinnge-Mongmit Road to its confluence with Kadan *chaung* (23° 5′ : 96° 12′) to (23° 7′ : 96° 14′).

(3) Nansit *chaung* (23° 5′ : 96° 14′).

(4) Shwegyin *chaung* one mile south of Kyaukmaw (23° 5′ : 96° 0′).

(5) One and a quarter miles north-east by north of Webaung.

In every case where working was going on the gold was obtained from stream gravels which were in most cases rather sparse. The area on Shwegyin *chaung* is the most extensive and occurs where the stream debouches into a jungle-covered plain composed of soil cap, gravels and calcareous tufa. The cementing effect of the latter and the changing of the stream course owing to the formation of travertine dams, does not encourage the hope of large quantities of gravel available for easy washing. The local

inhabitants report that before work was stopped by the Forest Department, earnings had been from Rs. 5 to Rs. 8 per day, per team of three men.

In Paungsho *chaung* active washing was being carried out by small parties of local villagers. The gold is coarse and rather angular and runs in grains up to more than a millimetre in diameter. Bamboo pumps are used for dewatering the pits excavated for the gravel and in all cases seen the washing procedure was the same. The gravel is placed in a rocking basket at the top of a launder about five feet long and with three-inch riffles. When a consignment of twenty baskets of gravel has passed over the launder the residue from the riffles is washed into a wooden pan for final separation. In this *chaung* the gravels are neither extensive nor thick.

In the tributary of Maunggwe *chaung* one mile south of Pinkan the bed of the stream is very bouldery and the gravels which occur between the boulders are sparse. Nevertheless the local villagers reported that they were able to wash about eight annas worth of gold per day in the rains. Just above the most southerly of the pits a vein of iron pyrites crosses the *chaung* but no gold has been detected in samples of it.

The occurrences are not of sufficient promise to attract capital and the amounts of gold produced not of sufficient quantity to warrant specific Government interference.

Graphite.

Bastar State, Eastern States Agency.

75. Flaky graphite was noted in granitic schists near Bora Kondesanvali (18° 31′: 81° 14′), and two miles south west of Kamaram (18° 25′: 81° 12′). The occurrences are not likely to be of any economic importance.

Mandalay district, Burma.

76. Graphite was noted by Mr. Clegg in a quartz vein in the calciphyres just over a quarter of a mile south-east of Tawyokyaung, Mandalay district (22° 19′: 96° 4′). The vein is about five feet thick and dips east at 20°. Attempts have been made to prospect it and an adit has been driven down the vein for about 20 yards. The graphite is impure and is of the nature of a graphite-quartz schist

Small flakes of graphite together with crystals of spinel and phlogopite characterise the contiguous calciphyres. The occurrence is not of economic importance.

Iron-ore.

77. Mr. Crookshank reports cliffs extending for 2¼ miles, of almost pure iron-ore at the top of the Bailadila ridge on the western side east of Kondapal (18° 50′ : 81° 11′). As these deposits have never been opened up it is impossible to estimate the quantity of ore present, but it must amount to many millions of tons. Patches of good iron-ore are common in the laterite which caps the ridge, but it would be impossible to say whether it is of good enough quality to be of economic importance without extensive sampling. One large deposit of almost pure hematite forms a considerable hill at point 3760 in the middle of the laterite plateau.

Bastar State, Eastern States Agency.

78. Mr. A. B. Dutt notes that boulders of magnetic iron-ore (magnetite) occur in association with hornblende granite at the bend of the Panlaung river about half a mile E. S. E. of Nyaunggyat (21° 6′ : 96° 21′), Yengan State. The ore is good but the quantity is indefinite, transport is difficult and it is probable that the deposit will never be worked, except by local Shan iron-smelters.

Yengan State, Burma.

79. Magnetite in fairly big crystals but in small quantity is also reported by Mr. Dutt to occur in granite-pegmatites in the hills about three miles E. N. E. of Lethagon (21° 1′ : 96° 12′), Meiktila district, and in lumps in pegmatitic granite in the hills about three and a half miles E. N. E. of Myaingtha (20° 52′ : 96° 13′), Meiktila district. The two latter occurrences are only of academic importance.

Meiktila district, Burma.

Lead-ore.

80. Quartz veins with galena have been noticed in the laminated shales at Karamtara (20° 41′ : 80° 48′) in Ambagarh Chauki *zamindari* close to the junction of the shale with the granite and porphyry. These are similar to the occurrences recorded last year further south at Thelkadand (20° 37′ : 80° 45′) in the Panabaras *zamin-*

Drug district, Central Provinces.

dari.[1] Evidences of further prospecting works, with disappointing results, have been observed at Thelkadand this year.

Jashpur State, Eastern States Agency.

81. Dr. Dey found traces of galena in the fault rock, 1 mile north of Singibahal (22° 33′ : 84° 0′) and Phardbahar (22° 25′ : 83° 55′).

Dehra Dun district, U. P.

82. Mr. J. B. Auden states that occasional pebbles of galena and pyrites are found in the *nala* about 550 yards W. S. W. of hill 4432 near Lhetta (30° 35′ : 77° 48′). The country rocks are sheared and contorted Chandpur phyllites, subject to landslides. No lode was located. It is unlikely that any extensive mineralisation has taken place.

Ochres.

Drug district, Central Provinces,

83. Instances of yellow and brown ochreous enrichments have frequently been noticed in the ferruginous shales of the Sanjari *tahsil* of Drug district. Both yellow and brown types have been met with. These are often quite soft and fairly free from gritty matter and may be of use as pigments. The ferruginous shales south-east of Kamkapar (20° 41′ : 80° 54′) are particularly rich in ochreous material.

Baramula district, Kashmir.

84. Dr. A. L. Coulson noted occasional pits in the decomposed upper portions of the Panjal trap forming the Poshkar ridge (34° 2′ : 74° 30′) in the Baramula *tahsil* of the Baramula district, Kashmir, where the indigenous workers had apparently worked ochres for local use. None of that seen was worth collecting.

Petroleum.

85. Charge of the office of Resident Geologist, Burma Geological Department, Yenangyaung, was held by Mr. E. J. Bradshaw throughout 1937. Besides advising on technical matters arising out of the administration of the oil-fields and on problems relating to leasing and development, the Resident Geologist was consulted on the drafting of the revised General Orders of the Warden, Burma Oil-Fields, made under the Rules under the Burma Oil-Fields Act, 1918.

[1] *Rec. Geol. Surv. Ind.*, 72, Pt. 1, p. 53, (1937).

Salt.

86. During the latter part of January, 1937, Mr. E. R. Gee again paid a short visit to the Salt Range in order to advise on the exploratory measures for rock-salt that are being carried out by the Northern India Salt Revenue. Within the Mayo mine at Khewra (32° 38′ : 73° 1′) he noted that appreciable development work had been carried out at the High and Intermediate Levels in the Buggy and Sujowal seams. This recent work made possible the mapping of these seams of rock-salt and he was thus able to suggest further extensions. At the Low Level, the Pharwala development tunnel had been continued eastwards and, as previously predicted by Mr. Gee, had proved the Buggy seam. The seam had turned out to be of excellent quality and a number of chambers were being excavated to the south of the tunnel. In the South Pharwala area, work had mainly centred around the sublevel where the Middle Pharwala seam was, as anticipated, proving to be a valuable source of supply. Mr. Gee suggested further extensions in these areas.

Rock-salt, Salt Range, Punjab.

Exploration tunnels for proving the rock-salt deposits of the area north of the present Khewra mine, of the slopes west of Chanuwala (32° 44′ : 73° 10′) and near the exit of the Makrach gorge (32° 40′ : 72° 53′) were also inspected. Mr. Gee reports that these tunnels have not been extended sufficiently far to allow the expression of a definite opinion but that the evidence so far afforded was promising.

He also examined the recent exploratory tunnels near Kalabagh village (32° 58′ : 71° 33′) and made a number of suggestions regarding further development.

A description of the rock-salt deposits of the Salt Range is included in a recent paper by him entitled 'The Economic Geology of the northern Punjab, with notes on adjoining portions of the North-West Frontier Province' published in the *Transactions* of the Mining, Geological and Metallurgical Institute of India, Vol. XXXIII, Pt. 3, (1937).

87. Mr. Das Hazra reports the occurrence of two saline springs in the Siwaliks of Udhampur, *viz.*, at Berga (32° 48′ : 75° 2′) and Suruin Sar (32° 47′ : 75° 2′). The water is drunk by the local people as an aid to digestion and as a cure for stomach ailments.

Salt springs, Udhampur district, Jammu, Kashmir.

88. Mr. H. M. Lahiri noted a hot spring at Tatwani (32° 8′ : 76° 11′) and a salt spring at Bagh (32° 1′ : 76° 11′), the latter issuing from Nahan rocks close to a fault.

Salt springs, Kangra district, Punjab.

Tin.

89. The area mapped by Dr. Iyer in Amherst district is by no means rich in minerals, but in the Kya-In township, in sheet 95 E/14, alluvial washing for tin is carried out on a small scale in several places. Veins and apophyses of granite carrying tin have impregnated the country rocks to some extent, and weathering and washing has concentrated the tin in a number of places. The localities where tin washing was noted by Dr. Iyer are as follows:—(i) Kawalawa *Chaung*, east-north-east of Paka *Taung*, (ii) on the path between Kawalawa and Anankwin, (iii) Thanbaya tin mines, (iv) Kawalawa tin mines, and (v) Dayingouk *Chaung*.

Amherst district, Burma.

In each place about ten men were employed.

Water (see Engineering and Allied Questions).

Wolfram.

90. Mr. A. B. Dutt reports the occurrence of wolfram in quartz veins traversing the coarse-grained biotite-granite about half a mile E. N. E. of Hill △ 3188, W. S. W. of Nyaunggyat (21° 6′ : 96° 21′), Yengan State. Several pits had been dug and one adit driven. The pits had been long abandoned but the adit was worked up to September, 1936. Mr. Dutt considers the deposit to be promising but points out that no good road exists to a railway station, the nearest being situated 30 miles away.

Yengan State, Burma.

Several abandoned wolfram workings were noted by Mr. Dutt in the granite hills about two and a half miles south-west of Nyaunggyat. The wolfram appears to occur only in small quantity and to be of little economic interest.

91. An old working, said to be of wolfram, was also noted by Mr. Dutt in the hill about two miles south-east of Thwingyaung (21° 6′ : 96° 13′), Meiktila district. This area was opened up during the War about 20 years ago. Mr. Dutt was unsuccessful in his attempts to locate wolfram in the working.

Meiktila district, Burma.

While at Kywegan (21° 3′: 96° 11′), Mr. Dutt identified for a villager some good specimens of wolfram, said to have been obtained from the hills east of Lethagon (21° 1′: 96° 12), Meiktila district. A thorough search, however, failed to disclose the place of origin of the specimens.

GEOLOGICAL SURVEYS

Burma Circle.

92. During the 1936-37 field season the Burma Circle consisted of Mr. E. L. G. Clegg Superintending Geologist in charge, Messrs. E. J. Bradshaw and V. P. Sondhi, Geologists, and Dr. L. A. N. Iyer and Mr. A. B. Dutt, Assistant Geologists. At the close of their field season's work Mr. V. P. Sondhi and Dr. L. A. N. Iyer were transferred to India from Burma, to reduce the party to the strength desired by the Government of Burma.

From the 1st April, 1937, a separate Burma Geological Department was created, consisting of Messrs. Clegg, Bradshaw and Dutt, who were placed on foreign service with the Government of Burma.

93. During the field season Mr. Clegg continued the extension of his survey of the Mogok Stone Tract by examining various outcrops in sheets 93 B/4, 93 B/3, 93 B/2 between Mandalay and Thabeitkyin, and then continued mapping in sheets 93 A/4 and A/8 north of Thabeitkyin.

The area south of Thabeitkyin is included in La Touche's map of the Northern Shan States[1] but no attempt was made by La Touche to divide the rocks into the calcareous and granitic rocks which were known to exist. Mr. Clegg found that all the isolated outcrops which protrude from the alluvium in the southern area consisted of either metamorphosed calcareous rocks, metamorphosed calcareous rocks intruded by granite, or solely of granites. The exposures commence at Mandalay Hill, which consists essentially of crystalline limestones and diopside calciphyres, penetrated on the eastern flank by granite and pegmatite dykes. The granite, which is excellently exposed in the quarries on the east side of the hill, varies from fine aplitic to coarse porphyritic biotite granite and in it quartz veins

Mandalay hill.

[1] *Mem. Geol. Surv. Ind.*, XXXIX, Pt. 2, (1913).

are common. The general strike of the granite dykes is N. 5° W. The calciphyre is very contorted and has veins of granite material injected along, as well as across, the bedding.

Kyanigan hills.

Seven miles north of Mandalay the Kyanigan hills are composed for the greater part of metamorphosed calcareous rocks with an acid igneous intrusion on the south-west. The calcareous series are generally fine-grained, banded, show local contortions and weather irregularly according to the composition of the bands; they consist of diopside-granulites containing free calcite, scapolite, diopside, quartz and felspar; occasionally, as one mile east of Kyanigan, iron pyrite is present. Other varieties include coarse crystalline limestone containing calcite rhombs up to half an inch in length, and a medium-grained calcareous quartzite consisting of a mosaic of quartz and a little felspar with interstitial calcite. The granite is mostly coarse, biotitic and gneissic; thin bands richer in biotite are almost schistose, and white bands consist almost entirely of tourmaline, quartz, and felspar. Sometimes a fine-grained biotite-muscovite gneiss occurs in association with the tourmaline granite.

Boywa hill.

Eleven miles north of Mandalay the isolated Boywa hill consists entirely of gneissic medium-grained biotite-granite.

Rocks west of Chaung-Magyi *chaung*.

In Sheet 93 B/3 a large granite boss lies to the west of the Chaung-Magyi *chaung*. West of this boss the Sagyin hills rise abruptly as a straggling line of irregularly shaped hills made up of crystalline limestone and metamorphosed calcareous rocks of a more impure nature. These continue intermittently to the north and form the calcareous hills to the north and south-west of Pinle-In; they are broken by granitic intrusions, which form outlying smaller intrusions of the massive boss to the east, and from which they are separated by an alluvial valley possibly overlying calcareous rocks. Northwards metamorphosed calcareous rocks are found bounding on the south another of these outlying granite intrusions immediately north by east of Nyaungwun.

Sagyin Hills.

The Sagyin Hills consist of massive white crystalline limestones which dip east by north at 42°. Some of these marbles contain rhombs of calcite up to three inches in length; others are finely saccharoidal. In the low hills just over a mile S. S. E. of Sagyin a little crushed calcareous gneiss

consisting of quartz, diopside, sphene, a little scapolite and felspar, occurs intercalated in coarse crystalline limestone. In the hills north of Sagyin, diopside, phlogopite and pink spinel were found to be common in the calciphyres near Tawyokyaung, whilst Hngetkyizin hill consists of white crystalline limestone and a medium-grained calcareous gneiss composed of plagioclase, a little orthoclase and microcline, diopside, sphene, a little quartz and epidote. The Pinle-In-Ywezu calcareous series is very similar to that found further to the south. It is intruded to the east by biotite-granite of both fine and coarse-grained types. The junction is not sharp and, near to it, granite has penetrated the calcareous rocks in a series of bands and small bosses. At the extreme north the hills end up in a tourmaline granite dyke in which crystalline limestone and diopside-calciphyre is caught up.

Pinle-In-Ywezu hills.

North-east of Nyaungwun the calcareous series consists of calciphyres composed mainly of calcite, a little diopside, sphene and scapolite and dips east by north at about 40°. In this area also granites intrude the series.

Hills north of Nyaungwun.

North-east of Magwe Taya calcareous rocks, mostly of calciphyre and calcareous gneiss, are found as a fringe to the main granitic intrusion to the east. Close to the boundary the latter is a tourmaline-granite.

The main granite mass of sheet 93 B/3 and 7 forms an almost impenetrable mass of mountainous forest country. The common type of granite present is normal biotite-granite but its texture varies from coarsely gneissic to fine-grained. The fine-grained is indistinguishable from the Kabaing granite of the Mogok area. Near the contacts of the granite with rocks of sedimentary origin, tourmaline-granite is common, as is for example seen (1) one and a half miles north of Sedaw, (2) below Sedaw inspection bungalow, (3) north-west of Kadetchin and (4) four miles east of Nyaungwun.

Main granite mass.

This main granite mass continues north into sheet 93 B/2 and 6, in the same type of mountainous forested country. Although the highest point (3,531) in this granite range lies to the south, the most prominent peaks along the watershed to the north are never less than 2,300 feet. Flanking this intrusion on the west are rocks of the metamorphosed

Pyingyitaung ridge.

calcareous series. These make up the ridge of Pyingyitaung south of Kokku and continue to the southern edge of the sheet; northwards they are found again in the valley of Kyunbyingyi *chaung*. West of the latter, the outer line of intrusion, which in this sheet consists predominantly of fine to medium-grained granite of the Kabaing type, makes up the hill mass of Ngawuntaung (1,217) in the south, emerges from the alluvium some three miles to the north to form Kaduda Taung and then from the calcareous series just over a mile further north to join the granite hills of which Taunggyun Taung forms the highest point. The latter hills continue to the north of the sheet but in the north, crystalline limestones, calciphyres and calcareous gneisses are very clearly seen caught up in the medium-grained granite on Chaunggyi *chaung* between Chaunggyi and Zibyugon.

Ngawuntaung-Kaduda Taung and Taunggyun Taung.

West of this line of intrusion in the south, Recent alluvium flanks the granites but to the north rocks of the calcareous series occur. The latter differ little from those to the south on the east side of the outer line of granites, but on the west, in the extreme north of the sheet, crystalline limestones occur in association with a hornblende series, the rocks of which Mr. Clegg regards as more metamorphosed types of the altered limestones, lavas, tuffs, and ashes found south of Male and in the Cretaceous series in sheet 93 A/4 north of Thabeitkyin.

Hornblendic series possibly altered Cretaceous series.

On the west side of the Nweyon and Ywathit *chaungs* olivine basalts of late Tertiary age protrude through the soil cap; they encroach across the river at the bend one and a half miles south-west of Konaing. Further west similar lavas occur in sheet 84 N/14 where they were mapped by Mr. V. P. Sondhi as forming the line of hills between the right-angled bend of the Irrawaddy below Thabeitkyin, to Singu.

Olivine basalts.

94. In sheets 93 A/4 and 93 A/8 Mr. Clegg continued northwards Dr. Iyer's mapping of sheet 93 B/1 and 5. Last year Mr. Clegg collected some specimens of massive limestone from an area about ten miles south-east of Tagaung from which Dr. M. R. Sahni isolated an *Orbitolina* of Cretaceous age. As it was obvious from the topographical map that this massive limestone series continued for some distance to the south, Mr. Clegg's endeavour was to see if it linked up with the Mogok series.

This work was only partially successful, as in the south of sheet 93 A/4 there is a pronounced change in the strike of the rocks. Nevertheless the strike of the less metamorphosed series in the north is found to conform, within the limits which might be expected in a very disturbed and intruded area, with that of the Mogok series to the south, and it appears fairly certain that Cretaceous rocks are included in part in the Mogok series, rocks which in the past have been classed as of Dharwar age. A gap of about three miles exists between definitely shelly limestone rocks and totally re-crystallised and homogeneous crystalline limestones of the Mogok series.

Disturbed area bounds Mogok series on the north.

The rocks of the area are metamorphosed to varying extents and they can be divided into three zones:—

(1) A northern, little altered zone consisting of quartz and felspar porphyries, calcareous tuffs, ashes, agglomerates, and limestone in which traces of fossils can still be seen. The quartz-porphyries form quite a considerable mass in the ridge and hills west of Baladokhta Taung and continue to two and a half miles W. S. W. of Nansein Taung. The shelly limestones occur mostly on the eastern side of Nansein *chaung* where they form a series of steep hillocks and small cliff sections and are very much intermixed with lavas and ashes.

Varying degree of metamorphism of the rocks.

(2) An intermediate zone composed of metamorphosed ashes, blotchy limestone, in sections of which no trace of organic structure can be seen but which, megascopically, looks fossiliferous, phyllitic rocks of ashy origin, serpentinised peridotite and crushed granite. The acid intrusions occur near the contact with the Mogok series, whilst the basic intrusions occur to the north and are more remote.

(3) A southern zone composed of completely metamorphosed rocks of the Mogok series in which granites of the Kabaing type, crystalline limestones, calciphyres and calcareous gneisses predominate. This series occupies the high mountainous tracts of the Pinkan, Kyaukyi and Shwe-u-daung forests.

No definite boundaries exist between the various zones but the limestone rocks can be taken as an indicator. In the least metamorphosed rocks to the north unmistakeable shells can be seen both with the naked eye and as traces in a section; in the more metamorphosed zone the limestones are blotchy and sometimes look almost brecciated owing to coarser fragments of calcite

in a finer grained groundmass; in the Mogok series the calcareous rocks of individual exposures preserve a more homogeneous texture and no blotchiness at all is seen.

In the Paungsho *chaung*, where a good section can be seen of the middle series, the rocks consist of fine-grained banded tuffs, in places very tough and slaty and at others schistose and gneissic. The more schistose and gneissic consist of hornblende, sometimes much chloritised, in an aluminous groundmass.

The same series of rocks passes eastwards into sheet 93 A/8, where a very brecciated zone exists and the change from blotchy crystalline limestones with intruded acid granites, as seen south of the Twinnge-Mongmit P. W. D. road, to lavas, tuffs, and ashes north of the road, is very marked and it certainly seems as though major faulting occurs along this line. Were it not for the blotchy limestones which occur on the south side of this line in sheet 93 A/8 and the blotchy limestones which occur with granite-gneisses and altered tuffs in sheet 93 A/4, Mr. Clegg would have no hesitation in inserting a fault along the line of the Twinnge-Mongmit road. Possibly the situation will become clear when further work is accomplished. What has eventuated from the survey is that the autochthonous rocks of the Mogok series may include metamorphosed derivatives of any stratigraphical horizon from the Chaung Magyis to the Cretaceous.

Amherst district.

95. Dr. L. A. N. Iyer continued the geological survey of the Amherst district begun by him in the 1935-36 field season, northwards in sheets 95 E/11 and 15, 95 E/14 and 95 I/1, 2, 6 and 7. Many of the observations recorded in the General Report for 1936, naturally apply with equal force to the area mapped during this field season. The main geological formations mapped were as follows:—

4. Laterite and laterite with gravel.
3. Moulmein limestone.
2. Granite intrusions and contact altered rocks.
1. { (*b*) Taungnyo series.
   { (*a*) Mergui series.

Traverses made during the season in the Ye and Kya-In townships have given some idea of the geological structure of the area.

Geological structure of the area.

Apart from the granitic intrusions, the sedimentary rocks of the Mergui and Taungnyo series have a general strike of N. W.—S. E. The main ridge of the Taungnyo series in sheet 95 E/14 appears

to be the axis of a synclinal fold, whilst in the eastern portion of sheet 95 I/2, the Zami valley occupies a synclinal basin, the rocks to the west of it dipping east and east-north-east, and the rocks east of it dipping west and west-south-west. In this latter area the rocks are shallow-water sandstones and coarse gravels, and are significant of a gradually silting up shallow basin.

Faulting.

Evidence of faulting is seen in the Moulmein limestone exposures, but owing to their isolation in laterite, these effects are not visible on the underlying rocks. Near Lutshan[1] (15° 48 : 97° 54′), Mr. Leicester has described the effects of strike-slip faults on the limestones and the Taungnyo series below. A similar phenomenon occurs in the south-east corner of sheet 95 E/13 on the western spur of Winpauk Taung. The dip of the rocks is east; near Kyauktaga (15° 47′ : 97° 59′), the dip becomes steeper and further south the rocks appear to have been affected by a pivotal fault with translatory movement, which has reversed the dip to the west. The south face of Allantaya Taung shows a smooth slickensided surface, and Karesaw Taung seems to have been faulted off from it. Minor faults and slips are a common feature in the limestone exposures.

Taungnyo series and Mergui series.

It has not been possible to divide the Taungnyo series from the Mergui series in sheets 95 E/15 and E/14. Mr. Leicester has suggested that the Taungnyo series is younger than the Merguis or that it must be considered to form the upper portion of the Merguis; no conclusive evidence for the complete separation of the two series has, however, yet been obtained.

The rocks of the Mergui series consist of sandstones, sandy shales and shales, and when affected by contact metamorphism are changed to quartzites, phyllitic mica-schists and phyllites. Where intense granitisation has occurred, the product is a biotite-granulite. The rocks of the Taungnyo series generally consist of sandstone and shales at times passing to quartzite and phyllite. The sandstones become coarse, gritty, and conglomeratic in the Zami valley.

Granite Intrusions.

The granite intrusion mapped in sheet 95 E/11 and 15 continues in a northerly direction into sheet 95 E/14 and thence sweeps round to the coast. Numerous veins and apophyses of granite also occur in the rocks of the Taungnyo and the Mergui series. A dyke of granite, four miles long, runs

[1] *Rec. Geol. Surv. Ind.*, LXIII, pp. 93-97, (1930).

south-south-east from Kawlawa, and with other minor intrusives is responsible for the impregnation of tin in this area in rocks consisting of coarse biotite-granite or gneiss, medium- and fine-grained aplititic rocks, and pegmatite. In some of the banded gneissic varieties, felspar and quartz form definite bands whilst bands rich in biotite also occur. Crushed bands in the series contain biotite, quartz, felspar, iron-ore and apatite. The felspar is mostly microcline with some microperthite. The pegmatite near Kawlawa (15° 40′ : 97° 57′) is composed of microcline, quartz, muscovite, tourmaline and occasionally epidote. Aplite veins were seen in the Myettaw stream.

Moulmein limestone.

The Moulmein limestone occurs as towering ridges rising precipitously out of the alluvium and laterite in the Kya-In township, and also overlying rocks of the Taungnyo series. The general relationship of the limestone to the underlying sedimentary rocks has been dealt with by Mr. Leicester[1]. From his study of the contact in the Beke Taung he concluded that the junction is undulating, and that both the series have been folded together. The limestone passes to a calcareous shale at the base and in the absence of faulting at the contact, there appears to be little if any unconformity. Mr. Leicester also mentions that no definite conclusion could be reached regarding the relation of the Taungnyo series and the Moulmein limestone until further contacts had been examined.

A number of contacts examined by Dr. Iyer during the last season, led him to conclude that the limestone has been highly folded in with the underlying rocks.

The limestone is white, grey or darkish in colour, saccharoidal, fine-grained, massive, partly crystalline or amorphous. The results of solution weathering are seen in giant stalactites on scarp faces and swallow-holes. At the northern end of Winpauk Taung and near Kyauktaga (15° 47′ : 97° 57′), the limetone is brecciated and veins of calcite cement the brecciated pieces. This is a characteristic feature of the Lower Plateau Limestone of the Southern Shan States.

Laterite and laterite with gravel.

Laterite usually occupies the low ground and foot-hills near the coast, forming a cap over rocks of the Mergui series, and is in course of formation at the present day. It is also found in the flat country east of the Taungnyo range in sheets 95 I/1, 2 and 95 E/13 in

[1] *Op. cit.* pp. 94-97.

association with local gravel and sand. Conglomeratic pebbles are often cemented by lateritic material.

96. Mr. A. B. Dutt, before commencing systematic survey work on the Shan scarps, spent about a week familiarising himself with the Palæozoic formations in the Sedaw-Zebingyi-Maymyo area and the metamorphosed rocks and granites east of Mandalay, Belin and Kyaukse.

In the map accompanying La Touche's memoir[1] the hill five miles east of Mandalay is shown as consisting of Mogok gneiss. According to Mr. Dutt, however, this hill is composed of alternating bands of crystalline limestones, diopside-granulites, calcareous carbonaceous sericite-schists and calcareous sericite-quartzite at the base and crystalline limestones on the flanks and summit.

The geology of the hills east of Belin and Kyaukse has been dealt with in a recent paper[2] by Mr. Clegg.

In the General Report for 1936,[3] in giving Mr. Clegg's ideas about the systematic position of the metamorphosed sediments of Kyaukse, it is stated that "the metamorphosed sediments mentioned, which consist of diopside-granulites, marbles and calc-sericite-schists will eventually be found to link up with the Coal Measures which overlie the Plateau Limestones in the Kalaw area to the south". The views expressed by Mr. Clegg have now been supported by Mr. Dutt's mapping in the area south of Kyaukse. The metamorphosed calcareous sediments of the Kyaukse area occupy the same stratigraphical position as the Coal Measures further south, inasmuch as both sets of beds overlie the Plateau Limestones and have the same general strike, N. N. W.—S. S. E., although locally, at Kyaukse, the strike is roughly E.—W. It should be noted, however, that the beds of this horizon at Kyaukse show evidence of having undergone a considerably higher degree of metamorphism than those of the southern area.

Yengan State, Kyaukse and Meiktila districts.

Mr. A. B. Dutt's main work consisted in the mapping of parts of sheets 93 C/3 and 7, C/4 and 8 and D/1 and 5. The country mapped is situated on the edge of the Shan Plateau in the Yengan State, and the Kyaukse and Meiktila districts. The western

[1] *Mem. Geol. Surv. Ind.*, XXXIX, Pt. 2, pp. 1-379, (1913).
[2] E. L. G. Clegg, "Note on Rocks in the vicinity of Kyaukse, Burma", *Rec. Geol. Surv. Ind.*, 71, Pt. 4, pp. 376-379, (1938).
[3] *Op. cit.*, 72, Pt. 1, p. 61, (1937).

portion of this area was previously mapped by Mr. P. N. Datta and the eastern portion by Mr. V. P. Sondhi whilst Dr. Cotter surveyed a small area along the Thazi-Kalaw road in sheet 93 D/1 and 5.

The geological formations mapped were as follows:—

(6) Alluvium.
(5) Granite intrusions and associated rocks.
(4) Red Beds.
(3) Metamorphosed sediments consisting of mica-schists and limestone.
(2) Coal Measures.
(1) Plateau Limestone with limestone conglomerate and breccia.

Plateau Limestone.

The oldest formation of the area is the Plateau Limestone which consists of grey massive limestones, much brecciated and traversed by numerous veins of calcite. Occasionally a limestone conglomerate or breccia is met with. The Plateau Limestone maintains its typical characteristics throughout the area examined, except near its contact with intrusive rocks where it has been transformed into metamorphic calcareous rocks such as calciphyre, an outcrop of which occurs south-east of Taungdaw (21° 16′ : 96° 18′).

Coal Measures.

Overlying the Plateau Limestone are the Coal Measures consisting mainly of shales, sandstones, conglomerates and quartzites, though occasional bands of shaly sandstones, coarse felspathic sandstones and limestones are also noticeable. The shales are greenish to brownish in colour and occasionally contain nodules of hardened clay, as for instance on the river bank N. N. W. of Kunaw (20° 58′ : 96° 27′). Conglomerate outcrops are generally confined to sheet 93 D/1 and 5, although an outcrop of metamorphosed conglomerate is seen in sheet 93 C/3 and 7. At the junction of the granite and the Coal Measures the sandstones are metamorphosed to quartzites. The junction between the Coal Measures and the Plateau Limestone is invariably a zone of high calcification and is often obscured by calcareous tufa. The general strike of the beds is N. N. W.—S. S. E. and the dip is either in an E. N. E. or W. S. W. direction, the amount of dip varying between 60° and 70°.

The metamorphosed sediments consist of mica-schists and greyish limestones and occupy a triangular area at the south end of sheet

Metamorphosed sediments.

93 D/1 and 5. They are largely intruded by igneous rocks and were previously mapped by Dr. Cotter as Chaung Magyis. Mr. Dutt is, however, inclined to think that they are really members of the Coal Measures, subsequently metamorphosed by the intrusion of a granitic magma, but that their exact correlation will only be possible when the unexplored area to the south has been examined; he has, therefore, refrained from assigning any age to them at present.

Red Beds.

Only a small outcrop of the Red Beds occurs in the area. They consist of brick-red to purplish soft sandstones, sometimes having a mottled appearance.

Granite intrusions and associated rocks.

By far the most predominant rocks are granites and porphyries. The granites are generally of the biotitic type and are often gneissic in the fine and the medium varieties. Locally they are porphyritic and with an increase of hornblende they grade into hornblende-granites. They are traversed by quartz veins and pegmatites; dark basic segregations are occasionally seen in them, while basic doleritic rocks showing ophitic texture were noted in them in three places. Another interesting rock type of the area is volcanic tuff which occurs in small outcrops and consists of angular and rounded fragments of quartz and felspar in a groundmass of quartz and sericite. The porphyries include both quartz and felspar-bearing varieties. They are found in lenses and rounded patches intrusive into the Coal Measures.

Sino-British Boundary Commission.

97. Mr. V. P. Sondhi's field season was spent with the Sino-British Boundary Commission and his field work was restricted to the area traversed by the Commission or by topographical survey parties, ration parties and patrols working in conjunction with it.

La Touche's published map of the Northern Shan States[1] extends to about two miles east of Tangyan (22° 29′ : 98° 26′ 30″), the road-head of the Commission, and east of this point Mr. Sondhi's work may be regarded as reconnaissance traverses, the formations alluded to being those described by La Touche in the memoir quoted.

Mr. Sondhi reports that for a few miles to the east of Tangyan, the plateau-like rolling country is occupied by Plateau Limestones, but as the foot of the great hill range, with its highest peak shown

[1] *Mem. Geol. Surv. Ind.*, XXXIX, Pt. 2, (1913).

as 6,758′, is approached, different members of the Lower Palæozoic rock formations, namely Namhsim sandstones, Hwe-Maung beds and Naungkangyi series, are exposed. From these a few fossils were collected. With the exception of a relatively narrow basin of Red Beds with interbedded fossiliferous limestone in the vicinity of Man Nagang (22° 16′ 30″ : 98° 33′) this Lower Palæozoic sequence lies in a north-south belt about two miles wide and is overlapped on the east by Plateau Limestones which form the Loi-se hill-range. Plateau Limestones then cover practically the whole of the country to within one mile of the Salween River; their general strike is N. N. W.—S. S. E. and they have strong easterly dips.

The gorge of the Salween in sheet 93 J/12 is walled on the west by an enormous well-defined scarp of Plateau Limestone, along the eastern base of which the river flows some thousands of feet below. The limestones rest directly upon shales and sandstones belonging to the older rock formation of the Chaung-Magyis.

The valley of the Salween forms not only an important physical feature, being almost 5,000 feet deep, but also an equally remarkable geological one, as it separates two distinct types of country. On the west, although Plateau Limestones predominate, there are widespread deposits representing different ages in the geological sequence, from the Chaung-Magyi series at the base to Red Beds and lacustrine deposits at the top. As soon as the Salween is crossed, however, the greater part of the country visited by Mr. Sondhi was found to be covered by older deposits of shales, phyllites, slates, and sandstones, considered to be equivalents of the various members of the Chaung-Magyi series. Plateau Limestone, Red Beds and lacustrine beds are also present in lesser quantities but nowhere have Lower Palæozoic rocks and Rhætic beds been identified.

Near Ta Manhsom (22° 13′ : 98° 36′), where the Salween was crossed, several good sections occur on the river banks. The rocks consist of tabular beds of quartzitic sandstones intercalated with thinner layers of dark sheared shale, which dip E. N. E. at from 60-70 degrees. These continue eastwards through Kawn-ye (22° 10′ : 98° 41′) to Panghsang, and show a gradual change in lithology and degree of metamorphism. Eastwards the relative proportion of shale and degree of metamorphism increase, until near longitude 99° sandstones disappear altogether and bluish green, lustrous phyllites are all that one sees.

At Panghsang (H 17)[1] the Nam Hka makes a sharp double bend, apparently due to an east-west fault passing through the area. South of the town, younger rocks are seen for the first time since leaving Ta Manhsom: the low hills immediately to the south of Panghsang are composed of hard grit and arkose and represent the base of the Red Beds which are well developed in the Mengma (L 16)[1] valley to the east. South of this occurrence, across the Nam Hka stream, Plateau Limestone appears as a line of crags and cliffs, and an extensive sheet of the same rock formation caps the phyllites north-west of Panghsang.

The Red Bed deposits mentioned above extend to the head of the Mengma valley and form steep hills to the north and south. On the track several good sections of their unconformable junction with the phyllites are exposed.

West of Monglem (N 15)[1] a belt of Plateau Limestone runs first to the northeast towards Ching Maw, (Q 13)[1] and then turning north runs through the line of the well-known peaks of Pola She (P 11)[1] and Hko Di Shan (Q 9)[1]. In the south the belt is over four miles wide but it narrows down considerably towards the north, where it presents a fault-scarp on the west, overlooking the Monghsaw (9 11)[1] valley. The limestones lie unconformably upon older phyllites, which here contain beds of tuff.

The phyllites and associated tuffs occur as an elongated inlier in the limestones, since on the east they are again wrapped round by limestones which join the western Pola She belt, on the north and south.

Red Beds of the Monghsaw area.

The phyllitic series underlying the Pola She-Hko Di Shan scarp is exposed in a limited area only, along the foot of the scarp. Immediately beyond it on the west, the country is covered by a large basin of Red Beds which overlap phyllite and in places come in direct contact with the limestone. On the east their boundary with the older rock formation runs practically due north and south, along the crest of the ridge that bounds the Monghsaw valley on the east. The rocks consist of deep red sandy shales and sandstones deposited on a base of coarse grits and arkose which form the crest of the ridge, and which dip to the west at high angles. East of Monghsaw, however, the dips change to the east, thus demonstrating that the

[1] Numbers in brackets are those of squares on the Sino-British Boundary Commission map.

structure of the Red Beds here is that of an asymmetric syncline, whose axis runs east of Monghsaw. A comparatively small area of the Monghsaw valley, roughly that occupied by the paddy fields around the village, lies under beds of incoherent sand and clays which were, no doubt, deposited in a lake in late Tertiary times, probably in the Pliocene. Their interest lies in the fact that they were found to contain beds of peat and lignite, but these are unlikely to be of commercial value.

Lake deposits, Monghsaw.

The Red Beds of the Monghsaw valley extend for some distance to the west, beyond the crest of the high hill range on the west of the village, and their basal grits lie directly upon light green phyllites which cover the western slope of the range. The phyllites are soft and easily weathered into light red soil, contain frequent veins of quartz and dip to the east. They continue to the Nam Hka, whilst across that stream, on the west, they are seen to become coarser grained, in so far as they begin to show individual crystals of mica and approach mica-schist in general characteristics. For about two miles up the slope on this western side of the Nam Hka they retain an easterly dip, but beyond, the dip changes to west. Where the dip changes they contain a well developed bed of marble of pure white colour and fine grain. Further west and east of the crest of the high range, there occurs another strong bed of similar marble which was traced in a continuous line for about six miles. This bed shows a westerly dip and is separated from the former by mica-schists.

Phyllites and mica schists of the Nam Hka valley.

To the north both these marble bands appear to die out temporarily, but re-appear in a few isolated outcrops along the same strike, between Pangsuk (M 10)[1] and Monghka (M 10).[1] Before reaching the latter village the mica-schists disappear and give place to the fine-grained gneisses on which Monghka is built.

Monghka gneisses.

In Mr. Sondhi's opinion the Monghka gneiss owes its origin to the soaking of mica-schists by a granitic magma, which at the same time dissolved the greater portion of the limestone bands, and left only isolated bluffs of undissolved marble.

For about ten miles to the north of Monghka nothing but these gneisses occur, but among these, bluffs of marble were noticed in

[1] Numbers in brackets are those of squares on the Sino-British Boundary Commission map.

several places, occurring approximately on the strike of the more regular beds to the south.

Panghsang-Lufang traverses.

The greater part of the country between Panghsang and Lufang was found by Mr. Sondhi to be occupied by shales and phyllites of about the same age as those occurring in the eastern areas already described; they were invariably found to dip to the east, and near Hsonglong (J 15)[1] and Vingnun (K 11)[1] to contain interbedded limestone.

Granite near Nya Wa.

At Nahpan (H 11)[1], there occurs a small basin of Red Beds and further north, near Vingmau (G 9)[1] and Nya Wa (F 7)[1] small patches of granite were mapped, intruded into phyllites and shales. A study of the thermal effect of these intrusions on the sedimentary rocks proved interesting, in so far as it tended to show that the origin of mica-schists in the eastern areas was not to be attributed to the thermal effects of granitic intrusion alone. Near Nya Wa the effect of the intrusion appeared to be confined to a relatively narrow zone in which the sedimentary rocks were indurated and silicified.

North-eastern Circle.

98. During the field season 1936-37 the North-eastern Circle was composed of Dr. C. S. Fox, Superintending Geologist (in charge), Mr. A. M. N. Ghosh, Geologist, and Mr. V. R. R. R. Khedker, Assistant Geologist. The entire party was engaged on surveys in the Garo Hills and the Khasi and Jaintia Hills districts of Assam, which lie between the Brahmaputra valley to the north and the plains of Sylhet and Mymensingh to the south.

Garo Hills, Assam.

99. Dr. Fox, in December 1936, spent a few days in Shillong assisting the Assam Government in an advisory capacity in regard to questions of limestone and coal. He next spent a few days with Mr. A. M. N. Ghosh in the Pynursla (25° 18′ : 91° 53′) and Laitlyngkot (25° 26′ : 91° 50′) area of the Khasi Hills (Sheet 78 O) for the purpose of settling the problem of the age of certain conglomerates and investigating an occurrence of lithomarge which Mr. Ghosh had found. Eventually, Dr. Fox proceeded to his own field of work, in the middle of December, 1936, south of the Tura Range, Garo Hills (Sheet 78 K/S. E.).

[1] Numbers in brackets are those of squares on the Sino-British Boundary Commission map.

As already reported in the General Report for 1936, [*Rec. Geol. Surv. Ind.*, 72, p. 40, (1937)], Dr. Fox had indicated a large hidden coalfield south of the Tura Range (Sheet 78 K) eastwards from the meridian of Tura (25° 30′ : 90° 14′), in a narrow strip five miles wide to the Simsang river between Siju Songmong and Rewak Songmong, in which 500 million tons of coal should be recoverable from a single seam of good quality which appeared to underlie the area within one thousand feet of the surface. Dr. Fox has been able to confirm his opinion as to the geological structure of this area, so that should the coal seam not fluctuate greatly in thickness and quality the reserves estimated by him can be regarded as probable.

Before Dr. Fox returned to headquarters on the 20th February, 1937, Mr. V. R. R. R. Khedker worked under his instructions in the Simsang valley, from above Siju Songmong to below Baghmara, for two weeks.

Khasi and Jaintia Hills district, Assam.

100. During the field season Mr. Ghosh completed the mapping of sheet 78 O/15 and a portion of sheet 78 O/11. Most of the area is occupied by the rocks of the Shillong series and the remainder by epidiorite (Khasi greenstone), granite and dolerite. Outliers of the Cretaceous and Eocene strata occur at many places.

In the eastern part of sheet 78 O/15, the Shillong series occupying the Umsi, the Umsong and the Umjar valleys consists of sericite-quartzite, hornblende-, hornblende-biotite-, garnetiferous sericite-chlorite-, and garnetiferous quartz-mica-schists, crumpled and closely folded together. Some of the hornblende-schists appear to be the metamorphic products of the Khasi greenstone. Quartzite with a slaty cleavage, quartzose schists and some slaty rocks occur on the plateau, east of a line joining Mawblang (25° 27′ : 91° 57′) and Jong Kaksha (25° 28′ : 91° 59′). Well bedded, jointed and variegated quartzite forms the principal member of the Shillong series in the other areas of the same sheet. As a rule the quartzite strikes N. N. E.—S. S. W. and has a high dip either towards the east or west, although in some places on the top of the plateau a very low dip is observed. On a jungle path, about a mile and a quarter W. N. W. of Wahkhen (25° 21′ : 91° 51′), the quartzite was found to carry hematite in a phyllitic matrix and loose pieces of a banded hematite-quartzite were noticed.

With the exception of conglomeratic quartzite on the Lum Marck (25° 25′ : 91° 44′)—Nonglwai (25° 24′ : 91° 44′) ridge, the Shillong

series in 78 O/11 is represented by argillaceous rocks consisting of shale, slate, carbonaceous phyllite and sericite-schist. The argillaceous series appears to underlie the quartzite, as it dips under the latter.

South and south-west of Mawphlang (25° 27′ : 91° 46′), the line of junction between the arenaceous and the argillaceous beds of the Shillong series is marked by a conglomerate, which is well developed in the Bagra valley, on the Laitsopliah (25° 23′ : 91° 46′) ridge and in the valley of the Umsohra. Its presence both on the hilltop and in the valley is explained by Mr. Ghosh as due to folding. The conglomerate is evidently absent west and north of Mawphlang. Huge blocks of conglomerate were noticed at several places in the eastern section of sheet 78 O/15.

The general structure of the area occupied by the Shillong rocks is believed by Mr. Ghosh to be a synclinorium, composed of asymmetric anticlines and synclines, which are well displayed amongst the quartzites; he notes, however, that folding is not noticeable in the beds of shale and slate. The strike of the system of folds lies between N. N. E.—S. S. W. to N. E.—S. W. and the rocks have a variable dip, mostly high and sometimes vertical. Local variations in the direction of strike occur, especially in the proximity of the granite masses.

The oldest igneous rock of the area is the Khasi greenstone, which is intimately associated with the rocks of the Shillong series. It has a dark grey to greenish colour and shows considerable variation in texture and composition. When fresh the greenstone is massive, well jointed and forms sheer cliffs. It exfoliates on weathering and decomposes into a characteristic orange-red clay. On the top of the plateau the greenstone forms low, elongated, dome-shaped hills.

The greenstone was evidently intruded into the Shillong series and was subsequently folded with them. Mr. Ghosh provisionally draws attention to the lithological similarity of the Shillong series and the associated epidiorite (greenstone) with the Iron Ore Series (Upper Dharwars) recognised by Dr. Dunn in North Singhbhum, Bihar.

The next younger rock is the well-known Mylliem granite, of which the largest exposure, around Mylliem (25° 30′ : 91° 49′), occupies an area of nearly 30 square miles. Mr. Ghosh has found inclusions of quartzite and schist and also xenoliths of greenstone in the granite, and in many places apophyses of the granite occur

in the foliation planes of the schists, while granite dykes are seen to cut the Khasi greenstone in the Umsohra valley. Basic segregations, *i.e.*, ovoid and rounded patches, also occur in the granite. Locally the granite is found highly crushed and granulated, with a streaky texture, due to glide planes separating dark crushed minerals such as hornblende, chlorite and, in some cases, tourmaline, from lighter minerals. In Mr. Ghosh's opinion the metamorphism induced by the Mylliem granite intrusions on the Shillong rocks is very small.

The direction of the main vertical joints of the granite lies between N. 5 E.—S. 5 W., to N. 60 E.—S. 60 W., thus showing a rough parallelism with the general strike of the Shillong series.

The youngest intrusive rocks are dolerite dykes that run both E.—W and N. E.—S. W. and traverse all the above rocks. From the freshness of the augite in the dolerite it is thought by Mr. Ghosh to be the same as the Sylhet trap and he concludes that the dykes are of the same period of igneous activity. The age of the Sylhet trap is regarded as pre-Upper Cretaceous as it is overlaid discordantly by fossiliferous Upper Cretaceous rocks in places along the southern scarp of the Shillong plateau.

The Cretaceous strata of the Khasi Hills are more limited in distribution than was previously supposed. Mr Ghosh considers that the beds that were mapped as Cretaceous, in his area, north of latitude 25° 20′, belong to the Cherra stage of the Eocene. Early in December 1936, Dr. Fox, who was accompanied by Mr. Ghosh, studied some of the scarp sections of the younger sedimentaries on the plateau of Thang Jnat (25° 18′ : 91° 54′) and came to the conclusion that the true Cretaceous beds do not extend north of Khyrwet (25° 19′ : 91° 54′), where the conglomerate, so well developed in the stream beds and on the motor road E. S. E. and south-east of Pynursla (25° 19′ : 91° 54′), is represented by a few scattered pebbles (in the cliff section west of Khyrwet). Mr. Ghosh has found that on the Cherrapunji plateau the Cretaceous beds also rapidly thin out in a northerly direction and cannot be identified north of Laitryngew (25° 24′ : 91° 56′).

On the Thang Jnat plateau Mr. Ghosh has found that the Cherra sandstone, which succeeds the Cretaceous, ends near Ryngain (25° 22′ : 91° 53′). Outliers of the Cherra sandstone, however, are seen at several places further north, as for example, that at

Mawlyngngot (25° 24′ : 91° 56′), where the stage is represented by a conglomerate over 50 feet thick overlaid by 50 feet of massive, false-bedded sandstone. Another outlier, east of Phansawrut (25° 28′ : 91° 53′), rests on a zone of lithomarge.

An unconformity exists between the Cherra sandstone stage (basal Eocene) and the underlying Upper Cretaceous strata, which is well displayed in the cliff sections at the eastern edge of the Cherrapunji plateau. Here the Cherra stage attains its maximum development. The unconformable relationship between the two sets of beds is best studied in the cliff face about three miles north of Cherrapunji. In this section the upper Cretaceous beds dip at 10°—12° and are overlaid by almost horizontal Cherra sandstone; about its base the sandstone contains pebbles and in places becomes conglomeratic. This basal pebbly sandstone becomes conglomeratic in a northerly direction, as at Laitryngew. The basal Cherra sandstone conglomerate was found by Mr. Ghosh on all the footpaths descending from the western edge of the main plateau into the valley of the Umiew river, at one place a 200 ft. thick band of an algal limestone coming below the main Cherra sandstone but above the basal Cherra conglomerate. In a few instances the conglomerate is wanting at the base of the sandstone.

The Cherra sandstone stage is conformably overlain by the Sylhet (Nummulitic) limestone stage, which consists of limestones, sandstones, shale and coal seams. The limestone is sometimes absent, possibly due to subterranean solution, but in places the Cherra sandstone passes imperceptibly into the upper sandstone. In such cases it is difficult to delineate the boundary between the two stages. Mr. Ghosh records that he did not find evidence of the beds of the Sylhet limestone stage north of a line joining Pyngkerdem (25° 21′ : 91° 54′) and Sohrarim.

Khasi and Jaintia Hills district, Assam.

Mr. V. R. R. K. Khedker, Assistant Geologist, left for the field on the 3rd February 1937, for the Garo Hills district, where he worked for a fortnight under Dr. Fox, and then proceeded to the Khasi and Jaintia Hills district, where he worked up to the 10th May, 1937, mapping the south-east portion of sheet 78 O/10 and the south-west portion of sheet 78 O/14. He found that the oldest rocks in this area are the Shillong series. Their general strike is N. E.—S. W., with most of the strata dipping towards the south-east.

Mr. Khedker recognises the following sub-divisions in the Shillong series :—

(1) Slates and phyllites, which occur between Sohiong (25° 30′ : 91° 43′) and Wah Umiam *nala*, with a N. 40°E.—S. 40°W. strike, and dips at high angles, varying between 60° to 80° towards the south-east. These include hornstone-like siliceous bands, felspathic schists, quartz schists, carbonaceous slates, arenaceous gritty laminated slates and phyllites. Locally these beds have been considerably crumpled and sheared.

(2) Conglomerates occur in three isolated outcrops :—half a mile west of Sohiong (25° 30′ : 91° 43′), in the vicinity of Kynsew (25° 33′ : 91° 44′) and one mile E. N. E. of Kynsew. These consist of pebbles and boulders of quartzite, embedded in a schistose micaceous matrix which is also arenaceous in places. The conglomerates occur interposed between a series of quartzites and the slates abovementioned and are seen along the western margin of the slates.

(3) Quartzites :—these rocks, which occur largely east of the slates, form the region to the right of the Wah Umiam *nala*, including Shillong itself and the surrounding plateau. Quartzites also occur towards the west of the slates, in the area between Nongthliw (25° 33′ : 91° 43′) and Dingshit (25° 31′ : 91° 41′). They are well bedded, low grade quartzites with thin irregular laminations of sericite and show current bedding. Those which are towards the west of the slates however have more sericite and are often foliated.

(4) Between Mawiong (25° 34′ : 91° 43′) and Nongti (25° 33′ : 91° 41′) and between Dingshit (25° 31′ : 91° 41′) and Mawkneng (25° 30′ : 91° 40′), there are belts of mica-schists.

(5) Between the mica-schists (4) and the masses of intrusive Mylliem granite—to the west of the former and south of the latter—there are belts of supposed paragneisses which, in Mr. Khedker's opinion, are probably connected with the intrusive Mylliem granite. He, however, believes that the whole series, 1—5, is the Shillong series.

Mr. Khedker has found that the Shillong series have been invaded by two igneous rocks—(*a*) a basic rock, now epidioritised, which

is presumably the Khasi greenstone; and (*b*) granite of the Mylliem type. This is in agreement with long established facts from elsewhere in the Khasi and Jaintia Hills. The epidiorite appears as sills along the bedding planes of the Shillong series. The granite occurs as stocks and bosses in the Shillong series.

A banded granite which covers a large area in sheet 78 O/10 and which has been described as a 'granite-gneiss' by previous workers, is also present. It is probable that this banded granite is a gneissic type of the Mylliem granite.

The Shillong series and the Khasi greenstone are traversed by quartz in veinlets to large reefs, which reefs are absent from the granites.

Two localities of a highly weathered gritty sandstone have been noted by Mr. Khedker as remnants of Cherra sandstones,—¾ mile north of Sohiong (25° 30′ : 91° 43′) and one mile S. S. E. of Laitartet (25° 34′ : 91° 44′).

North-western Circle.

101. Dr. A. L. Coulson continued to be in charge of the North-western Circle during 1937. The following officers conducted field work in this Circle:—Dr. A. L. Coulson, Baluchistan, Waziristan, North-West Frontier Province and Kashmir; Mr. W. D. West, Simla Hills; Mr. J. B. Auden, United Provinces and the Karakoram, Mr. H. M. Lahiri, Punjab; and Mr. P. C. Das Hazra, Kashmir.

Baluchistan.

102. When he investigated the water-supplies of certain areas in Baluchistan for the military authorities, in December, 1936, and January, 1937, Dr. A. L. Coulson entered that province from Waziristan by the Tanai—Gul Kach—Fort Sandeman road, thus enabling him to examine, with a view to their tentative correlation with his Waziristan sequence, the continuation into Baluchistan of the thick series of limestones and shales of the Toi Khula area which form part of the Janjal Plant series.

Near Fort Sandeman, the Kapip Khwara has cut a gorge through a series of shales, limestones and sandstones shown as Cretaceous on the 32-mile map of India, presumably following Vredenburg's mapping (unpublished). His published map of the Quetta-Pishin area[1] only extends to a short distance east of Hindubagh. Neither Cotter[2]

[1] *Rec. Geol. Surv. Ind.*, XXXI, Pt. 3, Pl. 18, (1904).
[2] *Op. cit.*, LI, Pt. 1, p. 10, (1920).

nor Fermor[1] makes any mention of this series of limestones and shales in their summaries published in the General Reports quoted; but Cotter has mapped the "sandstones and shales" of the Jalai Kalai area in sheet 39 E/6 as probably Upper Cretaceous.

Dr. Coulson[2] had tentatively referred the rocks of the Kapip area to the lower part of Dr. M. Stuart's Janjal Plant series in Waziristan, which the former considers as Lower Cretaceous or uppermost Jurassic. But three-quarters of a mile north-east of Nim Parao (31° 52′ : 69° 23′), in rocks which Dr. Coulson had thought in the field to be the same as those cut by the Kapip Khwara, he collected an ammonite which was identified by Dr. L. F. Spath as *Didymites*, a genus characteristic of the Lower Norian (Upper Trias). To the east of the Kapip gorge is a broad valley which the stream has carved through thinly laminated black shales with ferruginous concretions, apparently similar to the uppermost stage of the Janjal Plant series. In the rocks of the Kapip gorge are certain bands of ferruginous argillaceous limestones which contain fossil organic remains apparently algal in character.

Dr. Coulson has noted that the fundamental feature of the geology of the Nim Parao, Sambaza and Sri Toi areas to the north of Fort Sandeman is the occurrence of a faulted outlier of Siwalik rocks which has been preserved owing to the fact it has been faulted down into older rocks. The eastern boundary of this elliptically shaped outcrop is a fault, the Sri Toi fault, which, after running north and south through sheets 39 E/5 and 6, turns south-west in the latter sheet towards Zarmat and Khushkhalwai Sar after passing to the east of Sri Toi Post. Naturally, in field work with armed escorts, Dr. Coulson was unable to trace this fault along its entire length. He notes, however, that at Nim Parao, the fault seems to branch northwards and Nummulitic limestones and shales crop out between the two branches. Amongst the fossils collected by Dr. Coulson, Mr. H. M. Lahiri has provisionally identified *Nummulites* spp., *Assilina* spp., *Assilina granulosa*, d'Arch., and *Discocyclina* spp.

The western boundary of the elliptical outcrop of Siwaliks is also faulted, as ? Kirthar limestones and shales with no basal conglomerate are the first rocks met as the boundary is crossed.

[1] *Rec. Geol. Surv. Ind.*, XLVIII, Pt. 1, p. 12, (1917).
[2] *Op. cit.*, 72, Pt. 1, p. 73, (1937).

There has been very complicated faulting west of Sambaza and Kanikhwa China.

From $1\frac{1}{4}$ miles north-west of Sambaza, Mr. H. M. Lahiri has provisionally identified *Terebellum* cf. *distortum*, *Turritella imbricataria*, *Stylophoria* sp., *Turbo* sp., *Vicarya* sp., *Fistulana elongata*, *Trochosmilia* sp., *Astrocoema* cf. *numisma*, a *Cidaris* spine, *Nummulites* spp., etc. West of Sambaza *Nummulites* sp., *N. obtusus*, and *N. exponens* occur. *Assilina exponens*, *A. mammilata*, *Discocyclina dispansa*, and *Discocyclina* sp. occur in the faulted area at Kanikhwa China.

The longer axis of the Siwalik outcrop is at least 20 miles long, stretching from Nim Parao in sheet 39 E/5 to well south-west of the deserted militia post of Tungiwar in sheet 39 E/6. The constituent rocks comprise red and grey sandstones and sand-rocks, frequently argillaceous, grits, conglomerates, clays, etc. The more resistant conglomerates, grits and sandstones form ridges which at times have a considerable relative elevation over the general level of the country. Strong grey sandstones, reminiscent of the Nagris, form the Spera Zhara and Khushkhalwai Ghar; the general facies of the rocks is that of the Nagri and Dhok Pathan stages of the Middle Siwaliks. The strike of the Siwaliks is very variable in the Nim Parao region, but becomes north and south and later north-east and south-west in the Sri Toi area. When it is not nearly vertical in the south-western part of the outcrop, the general dip is to the north-west, being at times as low as 45°.

The Siwaliks are frequently covered by a mantle of recent deposits, which are possibly glacial in places. The streams appear to have been rejuvenated at no distant date, the recent deposits forming terraces at times, flat-topped masses capping vertical or highly dipping eroded edges of Siwalik rocks.

The older rocks to the east of the Siwaliks are exactly similar to those of the Toi Khula area in Waziristan. They are generally contorted and highly folded. In the Nawe Oba area, they are intruded by large bosses of peridotite which is now altered to serpentine. Cotter (*loc. cit.*) has noted two occurrences of chromite in these serpentines. The junction of these rocks and the serpentines is more or less parallel to the road in the gorge of the Torghara Manda for some distance. One or two little masses of serpen-

tine crop out to the west of the road. The shales have become very ferruginous near the junction and are very highly contorted and folded.

South Waziristan.

103. After his work on the water supply of certain areas in Baluchistan, Dr. A. L. Coulson returned to South Waziristan for a short period of field-work in late January and early February, 1937, before his visit to the Makarwal area in the Trans-Indus Salt Range. Conditions during his time in Waziristan were far from suitable for field-work owing to increasing disaffection amongst the tribes, and on the completion of his economic investigations at Makarwal, Dr. Coulson's further field-work in the Agency was stopped.

Dr. Coulson worked on sheets 38 H/15 and L/3 and the results of his short survey confirm his conclusions given in last year's General Report.[1] He made additional collections of Tertiary fossils from the Kirthar rocks north of the Shahur Tangi, north-west of Chagmalai Post (32° 20′ : 70° 5′), amongst which Mr. H. M. Lahiri has provisionally identified *Amblypygus sub-rotundus* (Dunc. and Slat.) and species of *Assilina* and *Alveolina*. The Kirthar limestones and shales are developed east of the Mastang Algad, south of Chagmalai Post, where they are faulted against ? Middle Siwalik rocks to the east and underlain, apparently conformably, by Laki shales and grits.

These Laki strata continue southwards through sheets 38 L/4 and 39 I/1 and 2 to the Shirani country west of Dera Ismail Khan, where they have been correlated with the Ghazij shales of Baluchistan.[2] They extend at least as far north as Kotkai (32° 25′ : 70° 2′) in South Waziristan, where Ranikot rocks make their first appearance.[3] Dr. Coulson is unable to state how far north from Kotkai the Laki strata continue or whether the Kirthar overlap on to the Ranikot. In his previous season's work, he found Neocomian belemnites *in situ* in the bend of the Shuza Algad a quarter of a mile south-east of hill 3314 (32° 32′ : 70° 6′), and the sub-Kirthar rocks accordingly are confined to the small area east of the northward continuation of the Mandanna Kach fault, between the left-hand bank of the Shuza and the Kirthar-capped ridge.

[1] *Rec. Geol. Surv. Ind.*, 72, Pt. 1, pp. 22-23, 23-24, 71-75, (1937).
[2] *E. Vredenburg, op. cit.*, XXXIV, pp. 87, 182, (1906); XXXVI, p. 252, (1908).
[3] *Op. cit.*, 72, p. 72, (1937); L. M. Davies, *Nature*, 139, No. 3514, pp. 414-415, (1937).

Additional belemnites collected by Dr. Coulson during his present field season have been sent to Dr. Spath for examination. The results to hand confirm Dr. Coulson's views that the belemnites from Haidari Kach (32° 21′ : 69° 59′), immediately underlying the Shahur Tangi Pab sandstones, may be of a slightly higher horizon in the Neocomian that those from the Danawat shales near Sarwekai Fort (32° 16′ : 69° 54′), Nai Kach (32° 23′ : 70° 4′) and other places.

Dr. Coulson now considers that the thick limestones associated with the Danawat shales, as at Sura Ghar (32° 18′ : 69° 55′), are more probably also of Lower Cretaceous age rather than lithological variants of the Pab sandstones.

North Waziristan.

104. Dr. Coulson is now convinced as a result of his examination of the specimens collected by him during his preliminary traverse[1] in February, 1936, that the massive limestone forming Zer Ghar (32° 59′ : 70° 6′), 2½ miles east of Miram Shah, in North Waziristan, should be correlated with the Takht limestone of the Shirani country, three miles west of Mughal Kot (31° 26′ : 70° 5′), and the Bobai (32° 18′ : 69° 39′) limestone of South Waziristan. Both are more bituminous than the Upper Jurassic (Callovian) limestone of Sheikh Budin (32° 18′ : 70° 49′) with which he also correlates them.

Peshawar district, N.-W. F. P.

105. In March, 1937, after work in South Waziristan had been stopped by tribal unrest, Dr. A. L. Coulson paid a visit to the Cherat (33° 49′ : 71° 53′) area (sheet 38 O/13) in the Nowshera tahsil of the Peshawar district, a brief summary of the geology of which has been given by Griesbach.[2] Dr. Coulson's work was in the nature of a reconnaissance survey, carried out under police escort in the regions bordering the disturbed tribal area of the Tirah. His mapping, however, brings out the complicated structure of the Cherat area.

The general strike of the rocks is E. N. E. and the Cherat ridge, on which the hill-station has been built, is the northern limb of an anticline which has foundered by strike-faulting. The oldest rock in the anticline is apparently a limestone of possible Jurassic age which crops out near Mir Kalan (33° 49′ : 71° 57′) and north of Jalala Sar (33° 47′ : 71° 51′). It is overlain by a series of several

[1] *Rec. Geol. Surv. Ind.*, 72, Pt. 1, p. 71, (1937).
[2] *Op. cit.*, XXV, Pt. 2, pp. 93-99, (1892).

hundreds of feet of shales and sandstones, possibly Cretaceous in age, the apparent thickness of which is greatly increased by strike-faulting. Dr. Coulson, however, found no belemnites in these beds.

The next higher rock in the sequence is the massive bituminous limestone with abundant comminuted foraminiferal remains, so far unidentifiable, which forms the main part of the Cherat ridge. Foundered parts of the crest of the anticline are formed of this limestone, which Dr. Coulson correlates with the Dunghan limestone of Laki age. It is the same limestone as Cotter's Hill Limestone[1] in the Attock district of the Punjab across the Indus river. The southern limb of the anticline is covered by a mass of Recent deposits to the south of which is a large stretch of Upper Tertiary rocks, striking north and south, and apparently extending into sheet 38 O/14.

Dr. Coulson noted two outcrops, three-quarters of a mile N. N. E. of Jalala Sar and a quarter of a mile south-east of the Post Office, of a peculiar slickensided basic rock, of specific gravity 3·19, which is igneous in origin. Sections of this rock show it is now mostly serpentine, but such structure as remains indicates the rock was originally a tachylite. The faulting and isoclinal folding are post-Murree and have affected this basic rock. Its relations with the rocks at Jalala Sar are masked; also, below the Post Office, it occurs between the Dunghan limestone and a quartzite of the Cretaceous beds and the secondary iron-oxide present prevents one from being able to determine whether or not it is intrusive into the limestone. It is probably an offshoot of the Tertiary basic igneous complex of Waziristan[2] and Baluchistan.

The Dunghan limestone is succeeded by a series of shales with lenticular limestones, at times algal and containing unidentifiable fossils, which are similar to Griesbach's Dag beds. As a result of the overfolding and faulting to which the area has been subjected, the relations of these Dag beds are at times difficult to interpret, but Dr. Coulson thinks that they are perfectly conformable with the Dunghan limestone and that they represent the Chharat series. However, he could find no representatives of the Nummulite Shale, the uppermost stage of Pinfold's[3] Chharat series.

[1] *Mem. Geol. Surv. Ind.*, LV, Pt. 2, pp. 93-95, (1933).
[2] *Rec. Geol. Surv. Ind.*, 72, Pt. 1, p. 74, (1937).
[3] *Op. cit.*, XLIX, Pt. 3, pp. 144-145, (1918).

The Dag beds are succeeded by typical Murree rocks which occupy most of the area between Dag (33° 51′ : 71° 49′) and Cherat. These generally dip very steeply S. S. E. towards the hill-station, forming an isoclinal syncline which succeeds the Cherat anticline. North of the Murrees, the Dag beds, Dunghan limestone and Cretaceous rocks again appear in the form of an anticline, the southern limb of which is strike-faulted. It is also faulted to the north by a strike-fault of very large throw against highly contorted slates and schists which Dr. Coulson correlates with the Attock slates.

Mardan district, N.-W. F. P.

In the latter part of March and in early April, 1937, Dr. A. L. Coulson commenced the geological survey of part of the newly created Mardan district of the North-West Frontier Province adjacent to the Buner tract of Swat near Rustam (34° 21′ : 72° 17′), working on sheets 43 B/3, 7 and 8. He had previously collected interesting specimens of porphyries from Shahbazgarhi (34° 14′ : 72° 9′) and other localities near this area, which he has described elsewhere.[1]

The chief rock cropping out in the area is a biotite-granite, sometimes containing hornblende. This occupies a large area on sheet 43 B/7 and the new road which was being constructed from Rustam to Swat by the Ambela Kandao (34° 23′ : 72° 26′) gave good opportunities for studying it. The rock is of the Engadine granite type and contains 74·30 per cent. of silica. The relations of this possibly Mesozoic granite, which Dr. Coulson has termed the Buner granite as it crops out largely in that tract of Swat, to the Malakand muscovite-granite (*see* page 41) and the soda-granite suite of the Khyber and the Mardan district, have not yet been ascertained. It is generally unfoliated, weathering into rounded tors, though at times foliation is strongly developed. Certain exposures are very coarse-grained, but the texture of the granite varies greatly within small distances. The rock contains numerous small roof pendants of hornfels rock belonging to the series of schists, thin limestones and amphibolitic rocks into which it has apparently been intruded. Greisenised rocks occur near the junction with the schists south of Kulian Darra (34° 22′ : 72° 20′).

The exact age of this series of schistose rocks, which are profusely intruded by epidiorites and amphibolites, is not at present known. They probably belong to the infra-Trias and the associated

[1] *Proc. Nat. Ins. Sci., Ind.*, II, No. 3, pp. 103-111, (1936).

basic rocks to the Carboniferous-Trias Panjal trap series. The associated basic rocks apparently do not cut the granite, though inclusions of basic rocks in this were noted by Dr. Coulson along the Ambela Kandao road.

Reference has been made in the economic section of this report (*see* page 30) to the excellent deposits of marble at Ghundai Tarako (34° 13′ : 72° 25′). This altered limestone is presumably the same Carboniferous limestone that occurs at Shahidmena (34° 9′ : 71° 17′) in the Mullagori country and in the Khyber Pass. So far Dr. Coulson has had no opportunity of studying its relations with the schistose series. It is also intruded by basic igneous rocks, though not so profusely as at Maneri (34° 8′ : 72° 28′).

Dr. Coulson has so far noted no occurrences of the Buner granite on sheet 43 B/3, but the schistose series and the massive limestones apparently crop out in force in that area.

Baramula and Uri districts, Kashmir.

106. After the conclusion of his work in the Hazara district of the North-West Frontier Province, Dr. A. L. Coulson paid a visit of inspection to Mr. P. C. Das Hazra in the Udhampur district of Jammu. He then made a preliminary traverse up the Liddar valley of Kashmir before commencing his work on the northern slopes of the Pir Panjal on sheets 43 J/4, 8 and 12 and 43 K/5 in the Baramula and Uri districts of Kashmir, where he worked from late May to the middle of August, 1937.

Dr. Coulson's work was undertaken with a view to joining up Mr. D. N. Wadia's work in the Punch *jagir* of Kashmir with that officer's maps of parts of the Baramula and Uri districts and the unpublished reconnaissance mapping of parts of the Gulmarg area by Mr. C. S. Middlemiss. Another season's work yet remains to be done.

Dr. Coulson is still uncertain whether or not representatives of the Salkhala series occur in the northern part of his area near Nambalan (34° 9′ : 74° 19′), but microscopic examination of the schistose rocks occurring here would appear to indicate that they are really highly altered tuffs of the upper part of the Panjal trap suite.

Apart from these possible, but doubtful, Salkhalas, the oldest rocks in the area are the Lower Palæozoic Dogra slates which crop out in force in the south-western part of sheet 43 J/8 and the north-western part of sheet 43 K/5, stretching from the Baramula district

into Uri district and Punch. They are unfossiliferous, strongly cleaved, black slates. The peaks of Mar Pathri (11,639 feet) and Khan Pathri (12,504 feet) are composed of these Dogra slates, whose thickness must be large.

The next higher series is the Tanawal[1], a strongly arenaceous series also apparently unfossiliferous, which overlies the Dogras unconformably. A basal conglomerate is developed in the Tanawals at their junction with the Dogras west of Chorinargi (34° 6′ : 74° 16′). The Tanawals strike north-west and south-east near the junction of sheets 43 J/8 and 4 and then, as they are followed towards and into 43 K/5, the strike becomes more southerly and the width of outcrop greatly increased. There is evidence of much folding in the Tanawals in the higher reaches of the Ferozpur Nala and the increased width of outcrop is due to repetition by folding. The Tanawals extend southwards into Punch and north-west into the Uri district, Kashmir. They must be several thousands of feet thick. At times the quartzites are felspathic. The high peak of Al Pathri (13,938 feet) is formed of Tanawals.

Generally the Tanawals seem to pass up more or less gradually into the Agglomeratic Slate. This is especially noticeable on the ridge connecting Al Pathri with Apharwat (13,592 feet), where the Agglomeratic Slate gets finer in grain and less siliceous as Apharwat is approached. Middlemiss[2] has recorded Gondwana plants from this locality. A rather coarse agglomerate is usually present and in this are fragments of Tanawal rocks which presumably were blown out by a large volcanic outburst that heralded the outpouring of the immense masses of Panjal trap. The Agglomeratic Slate conformably underlies the Panjal trap. It is apparently only a few hundreds of feet in thickness. It is faulted near Ningan Dor (34° 3′ : 74° 18′) and its outcrop is frequently masked by screes on the Apharwat ridge. It could not be traced in the valley of the Kubnai stream to the north-west of Washtu (11,027 feet). It crosses the Ferozpur Nala striking S. S. E., and then makes a right-angled change in strike under Hadibal (13,663 feet) and the other trap hills to the south-west. Advantage has been taken of its relative softness where the Chor Panjal pass crosses into Punch. The dip near Hadibal is about 15° to the south-east.

[1] D. N. Wadia, *Rec. Geol. Surv. Ind.*, LXVIII, Pt. 2, p. 147, (1934).
[2] *Op. cit.*, XLI, Pt. 2, p. 132, (1911).

Reference has been made in the petrological section of this Report to specimens of unusual basicity and acidity collected by Dr. Coulson from the Panjal trap suite in the Baramula district. Middlemiss[1] has already referred to the problems awaiting solution regarding this very interesting suite of rocks. There is an immense thickness (several thousands of feet) of trap in the ridge behind Gulmarg, the base of which is not shown. Extrusion of basic lava, presumably beneath the sea, was followed by a long continued succession of explosive outbursts, the materials of which were stratified as tuffs. Associated with this phase of explosive activity were outpourings of more acid lava, toscanitic in nature. These have since completely devitrified and, like the tuffs and the Panjal trap itself, many have been epidotised. Another form of alteration in the Panjal trap is the development of a tremolitic hornblende. Zoisitisation, chloritisation, and, to a lesser extent, serpentinisation, also have taken place. Mention has been made of the schistosity of certain tuffs which resemble Salkhala rocks. South of Ferozpur Nala, the dips of the Panjal trap are considerably flatter and the highest peaks of the Pir Panjal, including Shin Mahinyu, 15,113 feet, are composed of shallow-dipping trap. The isolated hill of Washtu, W. N. W. of Gulmarg, and Poshkar hill, east of Ferozpur Nala, are also composed of Panjal trap.

A constant, but narrow, band of what is presumably Upper Trias limestone and associated rocks crops out in the tuffs, running from north-east of Washtu to near Gulmarg, where its outcrop is masked by moraines. The same rocks crop out by Ferozpur Nala and stretch from here south-eastwards to the Basam Gali pass into the Sripartapsinghpura *tahsil* of the Baramula district. Middlemiss[2] mapped a broad syncline of these Upper Trias rocks further to the south-east, near Tosha Maidan. The only fossils found by Dr. Coulson were indeterminate corals from the limestones W. N. W. of Basam Gali. The relations of the Upper Trias to the Panjal trap and tuffs are obscure, on account of the folding to which all have been subjected. Vertical dips are common and overfolding occurs, but it would appear that the Upper Trias rocks lie in a highly compressed syncline and are stratigraphically above the trap. There was less explosive activity in the trap suite to the south-east and here the Trias seems associated with trap rather than tuffs.

[1] *Pal. Ind.*, N. S., Vol. XII, pp. 12-16, (1928).
[2] *Rec. Geol. Surv. Ind.*, XLI, Pt. 2, p. 129, (1911).

There is a small outcrop of very decomposed biotite-granite on the hill slopes above the Ferozpur Nala near Tangmarg. This granite shows graphic structure. It is apparently brecciated and intrusive into the trap suite and numerous small veins of quartz occur associated with it. This granite is post-Middle Trias, if the tuffs into which it is intruded be taken as that. There are no contacts with the Upper Trias. The granite is probably of the same age as that described by Wadia[1] as post-Permian. Another small outcrop occurs south of the Ferozpur Nala near Ringawari (34° 2′ : 74° 28′).

Reference has been made in the petrological section of this Report to the relatively fresh, and probably Tertiary, hypersthene-dolerite cropping out in the bed of the Ferozpur Nala near Tangmarg. This is obviously much younger than the Panjal trap suite. It is apparently overlain by Karewas.

Dr. Coulson collected numerous plant fossils from beds of Karewas near Linyan (34° 4′ : 74° 17′) on the banks of Ningle Nala at a height of about 9,500 feet, but so far these have not been identified. Another high-level outcrop of Karewas is near Chormargi. Middlemiss[2] recorded plant fossils from other localities in the Karewas and has referred[3] to the immense post-Karewa dislocations and uplift by which these Karewa beds now occur at high levels in the Pir Panjal. The general dip of the Karewas in the foothills of the Gulmarg area is away from the Pir Panjal towards the Vale of Kashmir. The Karewas in part at least are contemporaneous with the Pleistocene glaciation to which the area was subjected.

Apart from Recent alluvium, the youngest deposits in Dr. Coulson's area are the large masses of scree and moraine material which frequently obscure the solid geology.

Karakoram, Shaksgam, Aghil.

107. Mr. J. B. Auden joined the Shaksgam Expedition, under the leadership of Mr. E. Shipton, as geologist. The party of four Europeans left Srinagar on May 5th, following the route over the Zoji La to Askole, and crossing a new pass over the Karakoram Range leading from the Trango branch of the Baltoro glacier to the Sarpo Laggo glacier. Survey work was carried out down the Sarpo Laggo to the Shaksgam river, over the Aghil range by the Aghil Dawan, and

[1] *Rec. Geol. Surv. Ind.*, LXVIII, Pt. 2, p. 169, (1934).
[2] *Op. cit.*, XLI, Pt. 2, pp. 121-122, (1911).
[3] *Op. cit.*, pp. 136-137.

northwards up to the Yarkand River. Returning to the Sarpo Laggo, the Crevasse glacier, first discovered by Younghusband, was examined to its head, after which Mr. Auden crossed the Karakoram watershed into the Punmah, and returned alone to Askole. He reached Srinagar on September 4th *viâ* the Deosai plains. Until the topographical maps made by Mr. M. A. Spender, with the assistance of Messrs. Shipton, Tilman and Auden, have been prepared, it is impossible to make an accurate geological sketch map of the area traversed. Difficulties inherent in such a mountainous, and for the most part unsurveyed, country naturally prevented any detailed geological mapping being carried out. This area is included within maps 42 P, 43 M, 51 D (unpublished) and 52 A.

The sequence determined by Mr. Auden is as follows:—

> Mesozoic (marine Trias and Jurassic),
> Permo-Carboniferous (mostly marine),
> Sarpo Laggo series of slates, phyllites, schists, quartzites, greywackés, impure limestones.

The fossils collected by him, which will be described by Dr. M. R. Sahni, indisputably prove the existence of Jurassic and Permo-Carboniferous beds. The latter had previously been found along the Shaksgam by Professor Ardito Desio in 1929.[1] The Mesozoic limestones occupy a tectonic basin 16 miles in length, mostly along the southern Aghil range. These limestones are surrounded by the Permo-Carboniferous, which is well exposed along the Shaksgam valley, and up the west Surukwat river north of the Aghil pass. The underlying Sarpo Laggo series crops out extensively along the Sarpo Laggo glacier, up the Crevasse glacier, and among the northern Aghil ranges, extending northwards to the Yarkand River. They also clearly form a considerable portion of the Kun Lun mountains in Chinese Turkestan. Their age is considered to be mostly lower Palæozoic. A synclinal zone of red beds was found crossing the Surukwat river and extending up the Zug Shaksgam. These are possibly equivalent to the Tisnab beds of De Terra.[2]

There is no doubt from Auden's work, and the work of Desio in 1929, Hayden in the Pamirs in 1914, and De Terra in the Depsang in 1928, that a zone of marine Tethys sediments extends for many

[1] *Geog. Journ.* LXXV, p. 402, (1930).
[2] Geologische Forschungen im westlichen K'un Lun und Karakoram-Himalaya, pp. 51, 81, (1932).

miles just north of the Karakoram range. The northern boundary of the marine Mesozoic rocks must have been along the Kun Lun Range.

South of the Karakoram watershed there is a marked increase in metamorphism, and Mr. Auden now believes, with Desio, that some of the meso-grade para-gneisses of the Punmah and Biafo glaciers, around Askole, and along the Shigar river, are largely altered representatives of a Palæozoic series, including even the Permo-Carboniferous.

The sedimentary rocks have been invaded by granodiorites, dolerites and lamprophyres. The dolerites occur mostly among the northern Aghil ranges, while the lamprophyres are best developed along a zone between the Karakoram watershed and the Shaksgam, being abundant just north of K2 peak. Both granites and lamprophyres are post-Permo-Carboniferous. The granites are probably derived from the same magma as was intruded along the Indus valley.

Young volcanic rocks, almost certainly of Cretaceous-Eocene age, are found extensively across the Deosai plains.

Udhampur and Jammu districts, Jammu, Kashmir.

108. At the beginning of the field-season 1936-37, Mr. P. C. Das Hazra spent about four weeks with Mr. H. M. Lahiri in the Hoshiarpur and Kangra districts in studying and mapping the Siwalik rocks along the Hoshiarpur-Dharmsala road section. On the conclusion of this reconnaissance work, Mr. Das Hazra left to commence his systematic survey of the Tertiaries of the Jammu hills in the Udhampur district of Jammu and Kashmir. The area surveyed during the season is comprised in one inch to one mile sheet 43 P/1 and portions of sheets 43 P/2 and 43 L/13.

In the old maps[1] of the Sub-Himalayas, the Tertiaries of this area are divided into Mari, Lower and Upper Siwaliks; but Mr. Das Hazra, following Pilgrim's classification,[2] has recognised and mapped the following formations :—

Sub-Recent and Recent deposits.

Upper Siwaliks	Boulder Conglomerate stage Pinjor (Tatrot ?) stage
Middle Siwaliks	Dhok Pathan stage Nagri stage

[1] *Rec. Geol. Surv. Ind.*, IX, pp. 49, 155, (1876).
[2] *Op. cit.*, XL, pp. 185-205, (1910).

Lower Siwaliks { Chinji stage / Kamlial stage

——————————————————transition.

Murrees.

The Murrees, which occupy the whole of the north-east corner in sheet 43 P/1, are not a uniform or homogenous series, but are composed of at least two contrasted rock facies. One facies can easily be identified as the Lower Murrees, composed usually of hard, fine-grained, calcareous sandstones and purple splintery shales and nodular clays. The other facies is principally composed of comparatively soft fine to sugary textured sandstones of pale yellow, grey or grey-brown colour and dull red to reddish brown shales and clays. The rocks of the second facies show neither the high dips nor the crushing and crumpling which characterise the Lower Murrees; on the contrary, they have low dips (20°-40°) and form prominent dip-slopes and scarps. The sandstones show ripple-markings and, being well jointed, break into huge blocks sometimes measuring over 20 feet. The plant fossils obtained from these sandstones at Manch (32° 59′ : 75° 14′) and Ka (32° 58′ : 75° 11′), resemble very closely the plant fossils from the Murree and Kasauli beds described by O. Feistmantel.[1] The lithological characters of the second facies of Murree rocks are similar to those of the Kasaulis of Dharmsala (Kangra District) and so it is suggested that this second facies might possibly be of Kasauli or Upper Murree age. Rocks of typical Upper Murree age, comprised of Siwalik-looking sandstones and characteristic Lower Murree shales, were observed near Krimchi (32° 57′ : 75° 7′). However, it was not possible conveniently to map the two rock facies separately in this area in the north-east corner of sheet 43 P/1, and they have accordingly been classed together tentatively as Lower Murree.

In the south-west corner of sheet 43 P/1, the "Mansar-Suruin Sar" anticline, definite Upper Murrees pass conformably into Kamlials. Although no particular bed can be taken as the exact boundary between the two stages, yet the group characters of the two are markedly distinct. The approach of the Kamlials is indicated by the occurrence of massive beds of dark hard sandstone. In this area, it was noticed that a prominent bed of ossiferous clay-conglomerate was invariably present at the base of the massive sandstones,

[1] *Rec. Geol. Surv. Ind.*, XV, p. 53, (1882).

and as this bed was easily identified in the field, it was taken as the base of the Kamlials. A somewhat similar bed of ossiferous clay-conglomerate, found at the top of the Kamlials, served to demarcate the boundary between them and the succeeding conformable Chinji stage.

The Chinjis are essentially an argillaceous formation, being composed of characteristic brick-red to deep red clays, soft light-coloured sandstones and pseudo-conglomerates. The proportion of clays to sands is 2 : 1 at the base but 1 : 1 at the top.

The Chinjis are gradually succeeded by a vast thickness—over 6,000 feet—of massive, coarse sandstones of greenish grey or "pepper-and-salt" colour and inconspicuous clays of grey or blue-grey colour belonging to the Nagri stage of the Middle Siwaliks. The coarse sandstone is locally calcified and, on weathering, gives rise to characteristic 'balls' of various sizes and shapes at the foot of the hills.

In the Jammu-Udhampur road section in sheet 43 L/13, the Nagris are conformably succeeded by the Dhok Pathan stage; but in the Tawi section in Udhampur, sheet 43 P/1, the Nagris are directly succeeded by Upper Siwalik beds. The Dhok Pathan stage is most probably overlapped here.

The Dhok Pathan stage in the road section is succeeded by the Pinjor and Boulder Conglomerate stages of the Upper Siwaliks. The former stage is composed of coarse, crumbling, pebbly sand-rock and variegated silts and clays, and the latter stage of boulder conglomerates with inconspicuous sandy matrix.

The principal structural feature of the Murrees is the geniculate deflection at the crossing of the Biruin Nala where the strike of the rocks changes from N. W.-S. E. to N. E.-S. W. and later to E. by N.-W. by S. The cause of the bend is uncertain.

The chief tectonic features of the Siwaliks are the two north-westerly pitching anticlines and synclines. The axes of the folds are fairly straight, trending S. E.-N. W.; but in sheet 43 L/13, they swing to S. S. E.-N. N. W. The Mansar-Suruin Sar anticline in the south-west corner of sheet 43 P/1 is a highly compressed anticline with almost vertical limbs, the component beds dipping at 60°-85° N. E. and S. W. The anticline is followed to the north-east by a syncline, the northern limb of which, as well as the southern limb of the succeeding anticline, is entirely cut out by a low-hading reversed fault (Kishanpur fault). The Middle Siwaliks which occur in the syncline also dip at high angles. The high dips of the zones

of strata composing the above folds suggest that they were subjected to a severe compressional movement coming from the north. Beyond the Kishanpur fault, the principal structure is an asymmetrical anticline of the Lower Siwaliks which, in turn, passes into a shallow syncline containing the Middle and Upper Siwaliks. The Udhampur syncline is cut out to the north-east by the Murree boundary thrust-fault. The boundary fault trends roughly N. W.-S. E., but makes a sweeping curve on crossing the Biruin Nala. The inclination of the thrust plane varies from about 30° to about 70°.

109. During March and April, 1937, Mr. W. D. West continued his survey of the Simla Hills, the area mapped falling within the one-inch sheets 53 A/16, E/3, E/4, E/7 and E/8, in the States of Suket, Bhajji and Baghal.

Simla Hills, Punjab.

Mr. West first mapped the rocks occurring along the Sutlej valley between Chaba (31° 13′ : 77° 10′) and Talah (31° 15′ : 77° 15′). In this area there occur bands of massive pink and white quartzites, with subordinate purple slates, in the midst of the Lower Shali limestone. These bands are seen to be sharp folds closing upwards, and they are clearly the crests of anticlinal folds. Their position in the centre of the great Shali anticlinorium supports this view, and indicates that they form the lowest horizon of the Shali series seen in this area.

A final examination of the structure at Chaba confirmed the view previously held that there occurs here a subsidiary thrust-fault which brings a thick slice of the Upper Shali limestone and Shali quartzite to rest on the Madhan slates (normally above the Shali series). The Power Station is situated on this thrust mass.

Having thus completed the mapping of what may be termed the Shali area, Mr. West proceeded to map the Shali thrust west and south-west from Tatapani (31° 15′ : 77° 5′). Between Chaba and Tatapani both sides of the Sutlej valley are occupied by rocks of the Chail series. But at Tatapani the Shali series re-appear once more, coming up in the core of a pitching anticline of the Chail series, from which they are separated by the Shali thrust. From Tatapani the line of the Shali thrust on the south side of the Sutlej valley runs nearly due west for about eight miles, and then rapidly swings round through a right angle to run south towards Arki (31° 8′ : 77° 58′). In the same manner the strike of the rocks above and below the thrust also swings round.

At Tatapani the Chail series is thrust over the Lower Shali limestone, though a few feet of chlorite-schist intervene in places along the line of the thrust. To the west this bed of green schist gradually thickens, until by Kaslog (31° 15′ : 77° 58′) its outcrop is nearly a mile wide. As it thickens it becomes less schistose, and can be recognised as a definite volcanic rock, a common variety being full of amygdales of quartz and chlorite. South-west from Kaslog its thickness decreases, until by hill 5998 (31° 13′ : 76° 57′) it is finally cut out by the Shali thrust, which brings the Chail series to rest once more upon the Shali limestone.

Followed to the north-west from Tatapani this volcanic bed continues along the north side of the Sutlej valley, and it seems likely from Medlicott's observations (*Mem. Geol. Surv. Ind.*, III, 1864) that it joins up with the traps of Mandi State. These were described by McMahon, and are almost certainly Panjal trap. It thus seems possible that the Panjal trap is represented in the Simla area.

Southwards from △ 5998 the trace of the Shali thrust follows a very straight course, running almost due south towards Hat Kot (31° 5′ : 76° 58′). From △ 5998 to as far as the Bilaspur-Arki road the Chail series is thrust over the Shali limestone, which to the west is overlaid normally by the Tertiary rocks. But south of this road the Shali limestone is cut out, and the Chail series rests directly upon the Tertiary rocks, the Chail series forming an escarpment overlooking the low-lying Tertiary country to the west.

The Shali thrust has thus been followed to within about a mile and a half of Hat Kot. Further south it seems likely, from what is known of the strike of this area, that it will run first S. S. E. and then south-east. Should this prove to be correct, then it is likely that it will join up with the Giri thrust by Kandaghat (30° 57′ : 77° 7′).

As regards the age of the Shali limestone, its correlation with the Krol limestone cannot yet be regarded as certain. Between the last exposure of the Shali limestone west of Arki and the Krol limestone of the Krol mountain there is a gap of about 15 miles. Moreover it cannot be overlooked that the lithological sequence within the two series is not identical. The probability is that the two series are the same age, but the question must be left unsolved for the time being.

110. During the field-season 1936-37, Mr. H. M. Lahiri mapped sheet 52 D/4 and a portion of 43 P/16, lying in the Kangra district and the Chamba State, portions of 44 M/9, M/13 and M/14 situated entirely in the Hoshiarpur district and portions of 53 B/13 and B/14, lying partly in the Ambala district and partly in the Patiala State.

Kangra district and Chamba State, Punjab.

The geological formations met with in 52 D/4 and 43 P/16 are the Nahan or Lower Siwalik, the Middle Siwalik, the Upper Siwalik and sub-Recent deposits. The lithology of the various formations is in general the same as that given in previous reports on the areas to the south-west. It may be noted, however, that the Middle Siwalik sandstone, which contains only scattered pebbles in the southern and western parts of 52 D/4, becomes highly conglomeratic in the exposures in its extreme north-east corner. The Pinjor (Upper Siwalik) strata also become increasingly coarse to the north-east.

The central structure in this area is an anticline of Nahan beds which form the ridge with on it the villages Masrur (32° 4′ : 76° 8′) in 52 D/4 and Mastgarh (32° 13′ : 76° 0′) in 43 P/16. South-west from this ridge, there is a regular succession from the Nahans upwards to the Upper Siwaliks, all the beds being characterised by high south-westerly dips. The structure of the Upper Siwalik beds beneath the sub-Recent deposits of the Buhl-Dehar-Gáj valley, which occupy a large area in the eastern part of 43 P/16 and the south-western quarter of 52 D/4, is an asymmetric syncline, the strata of the south-west flank of which have low north-easterly dips whilst those of the north-east limb are steeply inclined as a rule. The Upper Siwalik beds of the north-east flank of the Masrur anticline are faulted against the Nahans of the Bohar Kawalu (32° 5′ : 76° 12′) ridge. This is the Gumber fault of Medlicott.[1] North-east of this fault there is again a regular sequence up to the Upper Siwaliks until the Shahpur valley in the north-east quarter of 52 D/4, where they are overlain unconformably by valley deposits of probable sub-Recent age. The Middle and Upper Siwaliks reappear north of this valley, their junction with the sub-Recent beds being a low-angle thrust well seen in some sections. The structure of the Siwalik beds north of this fault is an anticline pitching east.

[1] *Mem. Geol. Surv. Ind.*, III, p. 134, (1864).

Hoshiarpur district, Punjab.

Mr. Lahiri's present season's work in sheets 44 M/9, M/13 and M/14 completes the geological map of the Hoshiarpur district. The portion of the Siwalik range lying in these sheets consists, as in the area to the south-east previously noted, of Upper Siwalik beds, both the Pinjor and Boulder-conglomerate stages being present. The central portion of the range is composed of sand-rock and conglomerates belonging to the Pinjor stage, the Boulder-conglomerates being confined to its either edge. The uppermost 1,000 feet of the Pinjor stage in 44 M/13 is highly conglomeratic, the crestal regions of the range consisting entirely of these conglomerates.

The major structure of the Siwalik range is an asymmetric anticline, the strata of the north-east flank of which are characterised by low north-easterly dips, whilst the dips on the south-west limb, which are low in the crestal area of the fold, steepen progressively towards the plainward edge of the range. In sheet 44 M/13, the crestal beds of the main anticline are folded into a very shallow but broad syncline pitching north-west. The Hoshiarpur portion of the hilly ground east of the Sohan *nadi* in 44 M/13 consists of Pinjor beds which are thrust upon the Upper Siwalik boulder beds of the *dun* country on the west. This fault is the north-westerly continuation of the Satlitta fault[1] mentioned in the Director's General Report for 1933.

Ambala district and Patiala State, Punjab.

Mr. Lahiri mapped portions of sheets 53 B/13 and B/14 lying to the east of the Ambala-Kalka railway line in continuation of his previous work in the area to the west of the line. The geological formations are Subathus (Eocene), Nahans or Lower Siwaliks, Upper Siwaliks and sub-Recent gravels. The Subathus consist of greenish or brownish shales and occasionally limestone and carbonaceous shales. They are faulted on the south-west against the Nahans which form the low hills occurring to the south and south-east of Kalka. The Nahans, in their turn, are faulted against Upper Siwalik boulder-gravels on the south-west. This fault is of the reversed type and is the southerly continuation of that running along the eastern edge of the Pinjaur and Nalagarh *dun* noted in the Director's General Report for 1935.[2]

[1] *Rec. Geol. Surv. Ind.*, LXVIII, p. 67, (1934).
[2] *Op. cit.*, 71, p. 78, (1936).

The portion of the Siwalik range on 53 B/14 examined during the season consists, as usual, of Upper Siwalik beds. Both the Pinjor and Boulder-conglomerate stages are represented, the latter being confined to the northern flank of the range and the *dun* country to its north. The structure is, as in the Hoshiarpur area, an asymmetric anticline. The axis of the fold passes quite close to the plainward margin of the range. While the strata of the north limb of the anticline have low northerly dips, those of the south flank are steeply inclined as a rule.

Garhwal district, Tehri Garhwal State, Dehra Dun district, United Provinces, Sirmur State, Punjab.

111. Mr. J. B. Auden spent five months in the Himalayan foot-hills between November, 1936, and April, 1937, mapping on two miles to one inch map sheets 53 F/S. E., 53 J/N. W., S. W., S. E., 53 K/N. W., N. E. He has completed the survey of the outer Himalaya between Solon and the Ganges river and has remapped a portion of the area in Garhwal district described by Middlemiss in 1887.[1] An account of the salient tectonic features of this zone, including the results of a part of his survey during this season, has already been published and it is unnecessary to discuss here the structure of the area described.[2]

Mr. Auden has determined the following unconformities in the outer Himalaya of this region :—

(1) at the base of the Eocene, which lies on Simla slates, Krol limestone and Tal beds :

(2) at the base of the Upper Tal limestone, which in Garhwal cuts out the Upper Tal quartzites towards the south, as near Gadmola (30° 2′ : 78° 33′) :

(3) at the base of the Lower Tal shales, an unconformity which is not pronounced, and which over most of the area may be a disconformity ; phosphatic nodules were recorded many years ago at this horizon near Mussoorie,[3] and have recently been found by Mr. Auden at Masrani (30° 27′ : 78° 9′) :

(4) at the base of the two boulder-bed horizons of the Blaini ; the Nagthat quartzites appear to be cut out completely by the Blaini both at Kimora (30° 29′ : 78° 10′) and at Bhitarli Kalan (30° 26′ : 78° 3′) :

[1] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).
[2] *Op. cit.*, 71, p. 407, (1937).
[3] *Op. cit.*, XVII, p. 198, (1884) ; XVIII, p. 126, (1885).

(5) at the base of the Nagthat series in maps 53 F/14, 15, where there is a pronounced unconformity across previously folded Chandpur phyllites.

It is clear that there have been several periods of folding prior to the Tertiary era, but it is difficult to assess magnitudes of the diastrophism responsible for these unconformities.

Mr. Auden has traced the Tons thrust from Sarog (30° 42′ : 77° 44′) to Khand (30° 32′ : 78° 21′), where it appears to terminate abruptly along the Bhagirathi river against another major tectonic line which divides the Barahat series from the overlying Chandpurs. The Barahat series is a newly recognised group of rocks, consisting predominantly of quartzites together with limestones and occasional lavas. The quartzites resemble those of both the Nagthat and Tal series, but from their general relationships, Mr. Auden favours their correlation with the Nagthat (Jaunsar) series. They occupy extensive areas to the north-east of the Bhagirathi river and, like the Nagthat quartzites, show complex secondary folds. Near Pirhi hill (30° 26′ : 78° 32′) and Partabnagar, the associated limestones are mostly siliceous dolomites containing bands of pale chert; but towards the north-west this type disappears, metamorphism increases and the limestones occur as finely banded marbles similar to those in the Mandhali series south of Chakrata. These marble are to be seen near Guinota (30° 45′ : 78° 17′) and just north of the Barahat Rest House (30° 45′ : 78° 27′). Amygdaloidal lavas occur near hill 5838 (30° 30′ : 78° 28′) and may represent a local development of the Panjal traps. A volcanic suite, likewise associated with quartzites, occurs south of Chamoli (30° 24′ : 79° 20′).[1] The Barahat series extends to the south-east into 53 J/S. E., cropping out on Maniknath hill (30° 22′ : 78° 40′), and certainly joins up with the Chamoli group which Mr. Auden noticed along the Alaknanda river in 1932 in sheet 53 N/S. W. The south-west boundary of this series with the overlying Chandpurs is regarded as a thrust-plane and has been traced from 30° 46′ : 78° 17′ to 30° 24′ : 78° 32′.

A large intrusion of dioritic rock, grading into dolerite, occurs on the east side of the Kharmola Gad, just west of Guinota (30° 45′ : 78° 17′). This diorite is similar to that found on the ridge west of hill 7027 (30° 42′ : 78° 03′).

[1] *Rec. Geol. Surv. Ind.*, LXIX, p. 134, (1935).

Mr. Auden revisited a portion of sheet F/14 in the hopes of arriving at a better understanding of the Mandhali rocks. The typical banded phyllites of the Chandpur series (which have a striking resemblance to the Lower Cambrian slates north of Srinagar in Kashmir) only occur above the Bansa limestone, but some of the pelitic rocks below this limestone are very similar to those of the Chandpur series, and it is uncertain if the arbitrary boundary between the two series, previously drawn at the top of the Bansa limestone, has any tectonic significance. That the Mandhalis underlie the Chandpurs on both sides of the syncline running across sheet 53 F/14 seems indisputable, but the correlation of the Bhadraj quartzite horizon with the Nagthat series leads to the difficulty that the same quartzitic rocks both underlie and overlie the Chandpurs. Mr. Auden hopes to discuss this problem in a Memoir it is intended to write.

Southern Circle.

112. The Southern Circle consisted of Mr. H. Crookshank, Superintending Geologist, in charge, Dr. P. K. Ghosh, Mr. D. Bhattacharji, Mr. B. C. Gupta, and Dr. A. K. Dey.

Bastar State, Eastern States Agency.

113. Mr. Crookshank continued his mapping in Bastar State and completed parts of sheets 65 F/1, 3, and 7. He states that the mapping of both sides of the Bailadila ridge is now complete for about two-thirds of its length. It is now definitely established that the banded hematite-quartzites which cap the ridge are not a deep-seated formation, but lie more or less horizontally on the surface of the older sediments which form the flanks of the ridge. To the west of the ridge these ancient sediments are almost entirely sericitic quartzites. They differ greatly from the slates, shales, and phyllites so strongly represented on the eastern flank of the range. The horizontality of the base of the hematite-quartzites, and the way in which they appear to overlap the various beds of the older series, are believed to indicate the presence of an unconformity at their base.

Mr. Crookshank goes on to show that the banding of the hematite-quartzites in this area is probably not connected with the original stratification of the rocks. He considers that it is due to the deposition of iron-ore along the planes of cleavage or schistosity in ferruginous phyllites or slates.

In mapping sheets 65 F/3 and 7 Mr. Crookshank noted numerous small lenticular masses and two large patches of a rock which he regards as a diorite which has to a variable extent assimilated the surrounding hornblende-schists. This rock is commonly mineralised. Dr. Dunn examined the opaque minerals in it. He reported that the rock greatly resembles the vanadium-bearing ones of Bihar. The only ore minerals which he could find were ilmenite altered marginally to rutile, pyrite, and a little hematite. No concentration of ore-minerals likely to be of any value was seen.

Bastar State, Eastern States Agency.

Dr. P. K. Ghosh continued his mapping in Bastar State, and completed the geological survey of sheets 65 F/6 and 65 B/5.

On sheet 65 F/6 he noted the same sequence as that given in the General Report for 1936 with some variations, which are as follows:--

A series of amphibolites is associated with the calc-gneisses and ferruginous schists. These are probably a mere variation of the calc-gneiss.

Some basalts seen to the north-west of sheet 65 F/6 connect up with similar rocks mapped by Mr. Crookshank further to the north. Their field relations are by no means clear, but they appear to be definitely older than the dolerite intrusions in this region.

The calc-gneisses and ferruginous schists are overlain unconformably by quartzites in the north-west corner of sheet 65 F/6. In the same area andalusite and cordierite schists, gneisses, and phyllites were observed.

Phenomena representing assimilation and hybridisation are common in the granitic areas. The effects of these processes are particularly well seen in a suite of rocks closely resembling charnockites. These are well developed in sheet 65 B/5, where in the same exposure variations from acid to basic and ultra-basic charnockites were seen.

In sheet 65 B/5 aplitic gneisses, charnockite-like rocks, calc-gneisses, ferruginous schists, and quartzites of Archæan age occupy the eastern and northern portions, while the south and west consist of Cuddapah rocks. These differ from the Cuddapahs seen in other parts of Bastar and the Central Provinces, as quartzites overlie shales and limestones instead of underlying them. The Cuddapah basin is here faulted into the Archæan complex. This may be the reason why the basal quartzites were not seen.

Bhandara district, C. P., Nandgaon and Khairagarh States, Eastern States Agency.

114. Mr. D. Bhattacharji continued his mapping in the Bhandara district, Central Provinces, and in the States of Nandgaon and Khairagarh, Eastern States Agency, comprising parts of sheets 64 C/11, 12 and 16 and of 64 G/4.

The centre of this area is occupied by a large mass of even-grained and unfoliated granite, which shows marginal chilling with production of granophyric texture.

To the west of this lies an assemblage of conglomeratic grits, some of which are volcanic in origin, vesicular traps, rhyolites and felsites, with some phyllites and a prominent hard quartzite. These have been attributed to the Sakoli series by Mr. Bhattacharji.

To the east the basement grit of the Cuddapahs rests upon the granite and is succeeded upwards by the limestones.

Drug district, C. P.

115. Mr. B. C. Gupta continued his work in Drug district, and mapped portions of sheets 64 D/10, 64 D/14, and 64 H/2.

The area mapped resembles that described in the General Report for 1936 except that the two lowest formations, the banded hematite-quartzites and the phyllitic schists, were not exposed.

New features are the huge dykes of brecciated quartzite extending in a north-westerly direction across the granitic gneisses and porphyries. The cracks in these are generally filled with secondary veins and crystal aggregates of quartz. Another interesting observation is the marginal chilling of the granite to a quartz-porphyry. This has been noted in several areas, but the clearest one is the granite-porphyry junction in the bed of the Seonath river north of Dorke (20° 44′ : 80° 38′).

An analysis of quartz-porphyry collected by Mr. Gupta in the Drug district, was made in the Department Laboratory. It proved to be almost identical with analyses of the well known quartz-porphyries from Glencoe and Arran in Scotland. This is an important addition to our knowledge of these rocks, and proves the correctness of Mr. Gupta's views concerning them.

116. Dr. A. K. Dey continued his work in Jashpur State and mapped parts of the following sheets during the field-season 1936-37 : 73 A/4, B/1, B/3 ; 64 N/10, N/14, N/15 and 64 M/S.E.

Jashpur State, Eastern States Agency.

In addition to the rocks already mentioned in the General Report for 1936,[1] Dr. Dey noted some grits, sandstones and ferruginous shales near Patia (22° 58′ : 84° 1′) and in the Khuria highlands. These rocks occur in small discontinuous outcrops or as scattered rock fragments around the hills. The late Mr. Hiralal referred them to the Lameta series on account of their lithological characteristics and infra-trappean position. This correlation is, however, tentative, in the absence of fossil evidence, for similar rocks also occur in the Upper Gondwana formation. The base of the formation is nowhere clearly seen but there is little doubt that it rests directly on the eroded surface of the Archæans. These rocks are overlain by the Deccan trap, but owing to extensive weathering under tropical conditions the trap is altered to laterite. It is, however, possible to find by careful search fragments of basaltic rocks with the laterite. Another rock type not met with during the previous field-season is carbon-phyllite. It is found with the gneissic rocks at Chichli (23° 6′ : 83° 44′) in the Khuria highlands.

The stratigraphical sequence of the rock formations present in the area is given in the following table :—

Laterite.
Deccan trap.
? Lameta series (grits, sandstones and ferruginous shales).

Archæan	*Granitic suite*, consisting of granites, granitic gneisses, granodiorites, pegmatites, aplites, quartz-veins, etc.
	Iron-ore series, consisting of phyllites, mica-schists, hornblende-schists, amphibolites, chlorite-schists, talc-schists, etc.

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THE HINDU KUSH EARTHQUAKE OF THE 14TH NOVEMBER, 1937: BY A. L. COULSON, D.Sc., D.I.C., F.G.S., F.N.I., *Superintending Geologist, Geological Survey of India.*

CONTENTS.

INTRODUCTION.

Shock felt over large area in north-west India.

At about 16·30 hours (4·30 P.M.) Indian Standard Time[1] on Sunday the 14th November, 1937, an unusually severe earthquake occurred in the Hindu Kush, which was felt throughout the North-West Frontier Province and Kashmir and over large parts of the Punjab and also in the United Provinces, northern Sind and Baluchistan. The purpose of this short paper is to place on record the reports of this shock and to show that the epicentral area indicated by them accords well with that deduced from instrumental records in the Bombay and Calcutta Observatories. It is also shown that the focus of the earthquake was very deep-seated (200-240 km.).

NEWSPAPER AND OTHER REPORTS.

Lahore report.

According to an Associated Press message, dated Lahore, the 14th November, 1937, published in the Calcutta edition of the *Statesman* of the 15th November—

"Lahore experienced an earthquake shock of more than moderate intensity at 4·30 P.M. today, the shock lasting for over a minute.

[1] Indian Standard Time is 5 hours 30 minutes ahead of Greenwich Mean Time.

Cracks were noticed on the walls of some delapidated structures, but no serious loss was reported.

A few bricks were dislodged from the balcony of the General Post Office, and the tops of several high buildings were seen to rock while the shock lasted.

Four earthquake shocks were felt in Lahore last month, but to-day's was more severe than any since those of 1904[1]."

General report.

The Calcutta edition of the *Statesman* of the 16th November, 1937, stated :—

" The earthquake which occurred at Lahore at about 4·30 P.M. on Sunday (briefly reported in yesterday's *Statesman*) was felt at many centres in the Punjab, according to the *Associated Press.*

Reports show that tremors of varying severity were felt at almost all stations in a circle formed by Peshawar in the north, Bahawalpur in the west, Kangra in the east and Delhi in the south.

At Kangra another shock occurred at 1 A.M.

The tremors were most severe in the north of the Province where considerable damage to property occurred.

Hundred of houses were damaged in Rawalpindi city, while a number collapsed in the suburban towns.

A young Sikh girl, who was buried under the wreckage of a house in Rawalpindi, but was later extricated, is lying in a precarious condition in hospital, while a woman has lost an arm.

Several buildings were damaged in Peshawar, where a number of people were injured by falling bricks. No loss of life, however, is reported.

According to the Quetta correspondent of the *Statesman,* earthquake tremors were felt at Quetta on Sunday afternoon.

The Alipore seismograph, at 16 hrs. 33 minutes (I. S. T.°) on Sunday, recorded an earthquake shock of great intensity at its origin about 1,330 miles from Calcutta."

Peshawar report.

A Peshawar Associated Press message, dated the 17th November, 1937, published in the Calcutta edition of the *Statesman* of the 18th November, 1937, stated :—

"News has been received of a violent earthquake which occurred at 4·30 P.M. on Sunday last at Chitral and Drosh, resulting in considerable loss of property and serious damage to the fort. This has necessitated the troops being placed under canvas. No casualties are reported."

[1] 1905, *i.e.*, those connected with the Kangra earthquake of 4th April, 1905.

The following note was published under the heading "Kashmir Earthquake of November 14" in the issue of *Nature*, dated the 20th November, 1937. It is reproduced in full as it mentions other earthquakes that have been felt in Kashmir and its vicinity:—

"Nature."

"An earthquake of some strength occurred on the afternoon of November 14 in north-western India, especially in the province of Kashmir. That it attained semi-destructive intensity (degree I of the Milne scale) is clear from the slight damage that occurred at Srinagar, Abbottabad, and other places. The earthquake is of interest chiefly from its association with more violent shocks in the same province. Within little more than a century two earthquakes of Milne's highest order of intensity (III) visited Kashmir, one in 1828, the other in 1885. Another, of intensity II, occurred on December 4, 1865, in the district around Chamba (about 150 miles south-east of Srinagar), and two others, of about the same intensity as the recent shock, in that near Srinagar on August 28, 1916, and January 20, 1931. Of these earthquakes, by far the most interesting is that of May 30, 1885, studied by Mr. E. J. Jones, of the Geological Survey of India, whose brief report is published in the *Records* of the Survey (18, 221-227). In the small meizoseismal area of this earthquake, containing about 47 square miles, the destruction of villages was complete and about 3,000 persons were killed. The next isoseismal includes Srinagar near its east end, and within it large portions of the towns and villages were thrown down. Abbottabad lies a short distance to the west of this isoseismal. Thus, it would seem that the origin of the recent shock may have been connected somewhat closely with that of its much stronger predecessor in 1885."

REPORTS OF METEOROLOGICAL OBSERVERS.

The following is a summarised tabular statement of the reports of meteorological observers received by the Director, Geological Survey of India:—

Place.	Indian Standard Time.	Number of shocks.	Duration of earthquake in seconds.
Ambala	16·35	2	1(?)
Bhakkar	17·20 (obviously wrong).	4	more than 90.
Cherat	16·32	many	80
Dehra Dun	16·32	1	2·3
Dehra Dun	16·30	2 with interval of a few minutes.	first—20 second—2·3.
Dera Ismail Khan	16·33	4	120

Place.	Indian Standard Time.	Number of shocks.	Duration of earthquake in seconds.
Drosh	16·30	1	132
Drosh	16·35	more than 10	90
Gilgit	16·22-23	several	10 (? each shock).
Gurais	16·35	5	70
Isa Khel	*16·30	3	180
Kabul	15·42 (? Afghanistan time).	1	90
Kargil	17·00 (obviously wrong).	3	2 (?)
Lahore	16·30	2 with a few seconds between.	60
Mianwali	16·30	5	120
Multan	16·30	..	120
New Delhi	16·28	1	105
Peshawar	16·28-32	10 maxima	220
Rawalpindi	16·30	3-4	180
Roorkee	16·30	3	60
Sialkot	16·32	3	30
Simla	16·32	1	12
Sonamarg	16·35	2 with interval of 2 seconds.	110
Srinagar	16·37	5 with intervals of 2-3 seconds.	8 (? each shock).

Detailed reports from Rawalpindi district.

In addition to the above meteorological observers' reports, the Director of the Geological Survey of India has received from the Deputy Commissioner, Rawalpindi, a valuable tabular statement embodying the reports of 53 observers in different *tahsils* of the Rawalpindi district. The duration of the shock is variously

estimated from 300 to 3 seconds, the average of all estimates being just under 90 seconds. The greatest number of shocks observed was eight.

ANALYSIS OF OBSERVERS' REPORTS.

Isoseismal lines.

The isoseismal lines given in the sketch-map forming Fig. 1 have been drawn from the details given in the foregoing meteorological observers' reports, due account being taken also of the newspaper reports. They show the intensity of the shock according to the modified Mercalli intensity scale (Heck, 1936, pp. 55-56).

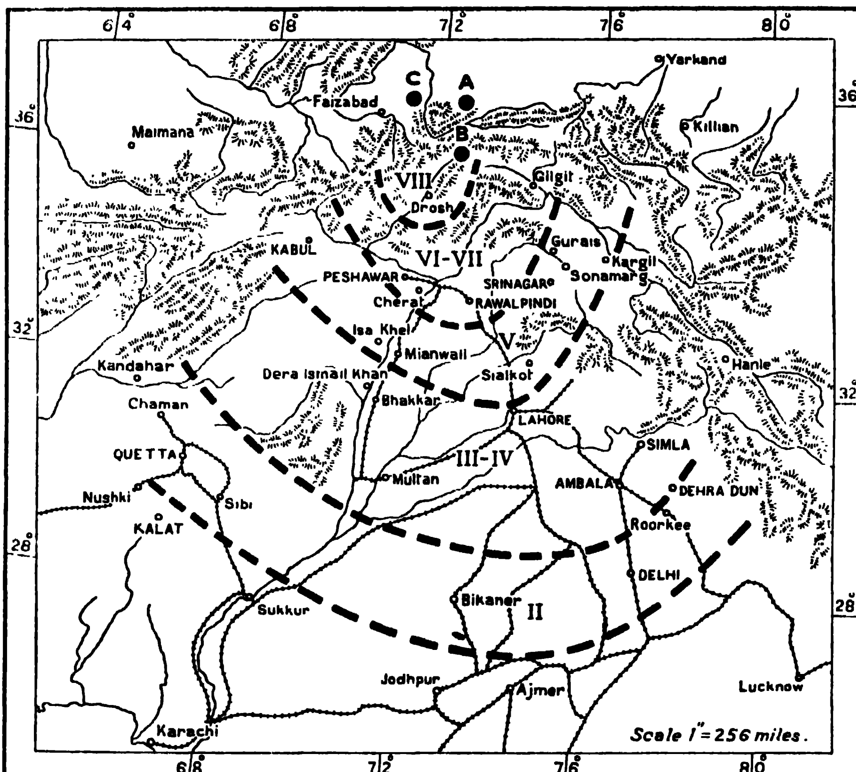

FIG. 1.—Sketch-map of north-western India showing the isoseismal lines (modified Mercalli scale) of the earthquake shock of the 14th November, 1937—

A.—Epicentre calculated by Bombay Meteorologist, if earthquake was deepseated.

B.—Epicentre calculated by Bombay Meteorologist, assuming a normal depth of focus.

C.—Epicentre calculated by Calcutta Meteorologist.

The observers' reports indicate that the epicentral region of the shock of the 14th November, 1937, is in the Hindu Kush mountains near Drosh in Chitral. On account of the absence of reports from this region, one cannot state whether or not the shock attained a greater intensity than VIII in the mountainous regions north-west of Drosh.[1] The shape of the isoseismal lines, however, would seem to indicate that the epicentral region was not very large and that it is possible that the maximum intensity of the shock above the focus did not exceed intensity X.

Intensity VIII.

Two reports were actually received from Drosh. One merely stated that the walls of the Telegraph building were cracked and that no details were to hand from outside. The other stated that buildings fell down and that a ground fissure occurred. The newspaper reports indicate considerable loss of property there.

A rumbling noise was heard during the shock by one observer.

Intensity VII-VI.

It is not possible to separate intensities VII and VI. In this region, the earthquake was accompanied at Gilgit by 'an aeroplane sound.' The river bank slipped at several places and rocks fell from the mountain-side in two localities. 'It looked like a dust storm all along the river and mountain where slipping occurred.' A 'whisking' sound was heard at Gurais and the walls of the fort cracked and all chimney-tops were dismantled. No sound was heard in Peshawar, but the verandah on the third floor of a new building in the Cantonment collapsed. Older bungalows had moderate falls of plaster. A few buildings were cracked and big stones fell down from the hills near the hill station of Cherat and blocked the roads. There was considerable damage to the tops of big buildings at Rawalpindi; also *pakka* huts were affected. Sounds were not generally heard accompanying the shock but in various parts of the Rawalpindi district, the noise was compared to 'autumnal winds,' 'speeding train,' 'thundering,' 'rolling stones' and 'a washing sound.' In interpreting newspaper reports from Rawalpindi, due consideration must be given to the prevalent style of buildings.

[1] The modified Mercalli scale has a maximum intensity of XII, when total damage occurs. In intensity VIII, damage is *slight* in specially designed (brick) buildings; *considerable* in ordinary substantial buildings with partial collapse; *great* in poorly built structures.

The report from Sonamarg stated that the noise before and after the shocks resembled that made by the start and closing down of a rice mill. The report from Srinagar compared the noise to the 'cracking of walnuts by the fist.' Two boys fell down from windows at Srinagar and received injuries. It would seem that the intensity of the shock at Lahore was just between V and IV.

Intensity V.

INSTRUMENTAL RECORDS.

The following details of the shock of the 14th November, 1937, were kindly supplied by Dr. K. R. Ramanathan, Meteorologist, Bombay, who also enclosed a contact copy of the record of the N.-S. component of the Milne-Shaw seismograph obtained at Colaba :—

Bombay.

Station.	Time of arrival of P (observed).	S—P interval.	Distance assuming normal depth of focus.
	Indian Standard Time.		
	H. M. S.	M. S.	
Agra	16 30 44	1 55 (?)	10·3°
Bombay	16 32 5	3 16	17·8°
Calcutta	16 32 40	3 36	19·9°
Kodaikanal	Reported time is wrong.	4 35	26·8°

The Bombay Meteorologist stated that the time of origin deduced from the data of Agra, Bombay and Calcutta and Jeffrey's normal table of travel-times is 16 h. 28 m. 10 s. and the position of the epicentre 36·5° N., 72·5° E.

He added that the Bombay seismograms show evidence that the earthquake was a deep focus one with a depth of focus of about 200 km. (sP-P being 1 m. 0 s.). If this depth of focus be assumed, the position of the epicentre will be shifted towards the north by about a degree. To come to a definite decision on this point, data from other stations and, preferably, also some original seismograms, should be examined.

Calcutta.

Dr. S. K. Pramanik, Meteorologist, Calcutta, kindly supplied the following details of the E.-W. component of the Omori-Ewing seismograph at the Alipore Observatory, Calcutta, as recorded on the 14th November, 1937 :—

Phase.	Greenwich Mean Time.			Epicentral distance.
	H.	M.	S.	
iP	11	2	42	2,330 km. (1,450 miles).
isP	0	3	53	
iS	0	6	18	
sS	0	7	22	
F	12	31	0	

He noted that the intensity was great with maximum movement 'in secondary'. The shock was of deep focus and the focal depth according to the Brunner chart was 240 km. The epicentral region was possibly at about 37·5° N., 71·5° E.

GENERAL DISCUSSION.

Instability of Hindu Kush well-known.

The instability of the region between the north-west Himalayas and the Hindu Kush is well known. In his classic work on the seismic phenomena of British India, Montessus de Ballore states (1904, p. 155) :—

"A single, but disastrous earthquake is known in Badakshan, northwards of the Hindu Kush, and this renders a great instability probable. Of Chitral nothing is recorded."

He also states (pp. 157-158) :—

"Kashmir is certainly the most unstable district of the region (North-West Himalayas). Earthquakes are both disastrous and numerous there. There are plenty of general causes explanatory of this instability in the geology of the country. The Himalayan fold is deflected there and spreads out in front of the Karakoram massif, so that summits of upper palæozoic and mesozoic formations tower over the depression of Kashmir, about 100 kilometres in length, the direction of which is nearly S. E.—N. W. The folding has reached a great amplitude there and the

folds have been twisted and even crushed. All these features cannot be explained without immense dislocations originated by the sharp change in direction of the Himalayan chain, and the instability proceeds from these disturbances.

The neighbourhoods of Peshawar, Rawalpindi, and Attock are very unstable, without having suffered to any great extent. A great dislocation, crossed by numerous secondary faults, separates the tertiary basin of Rawalpindi from the ancient rocks. So we can suppose that the forces from which these faults have proceeded manifest themselves still in the shape of earthquakes. Ruins, at least partially of seismic origin, are seen in many ancient castles built on the hill-tops."

The last earthquake of note that occurred in this neighbourhood was that of the 1st February, 1929 (Coulson, 1929 and 1930). The epicentre of the present Hindu Kush earthquake is obviously some distance to the north-west of that of the 1929 shock. When describing the 1929 shock, I concluded (1929, p. 288)—

"That the depth of focus of this earthquake might be such that the usual rates of propagation of the long waves (and of the other waves) are inapplicable."

Additional support was given to this view with the further instrumental records available at the time of my second paper (1930, pp. 442-443).

From the evidence shown in the seismograms of the 1937 shock at Colaba (Bombay) and Alipore (Calcutta), there seems little doubt that this shock was a deepseated one (200-240 km.). Admitting this, then the epicentre according to the Bombay Meteorologist is about 37·5° N., 72·5° E., and according to the Calcutta Meteorologist about 37·5° N., 71·5° E. Both these estimates correspond well with the conclusions drawn from observers' reports.

FORESHOCKS AND AFTERSHOCKS.

There were several shocks felt in the higher intensities areas prior to the main shock of the 14th November, 1937. Thus shocks were felt at Drosh on the 9th September (also felt at Gulmarg), 29th October (also felt at Cherat, Kabul, Lahore, Peshawar and Srinagar), and in the very early hours of the 8th November (also felt at Gilgit, Gurais, Peshawar, Rawalpindi and Srinagar).

Foreshocks.

It is interesting to note that the shocks felt in Ambala, Dehra Dun, Lahore, New Delhi, Roorkee, Simla and Srinagar at about 6·55 I. S. T. on the 20th October, 1937, seem to have had their epicentre in the north-west Punjab and cannot therefore be considered as foreshocks of the Hindu Kush earthquake of the 14th November, 1937.

Up to the time of writing this note (17th December, 1937), records have been received from Drosh of aftershocks which were felt there on the 16th, 19th and 21st November, 1937. It would appear that equilibrium apparently has been attained temporarily once more until the accumulated stresses are again relieved, either by a sudden shock or by a shock heralded by a succession of foreshocks.

Aftershocks.

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ON KHOHARITE, A NEW GARNET, AND ON THE NOMENCLATURE OF GARNETS. BY SIR LEWIS LEIGH FERMOR, O.B.E., D.Sc., F.R.S.

CONTENTS.

I. KHOHARITE.

In September 1912, in a paper entitled 'Preliminary Note on the Origin of Meteorites'[1], I suggested that the curious bodies known as chondrules found in so many stony meteorites must once have been garnets. This suggestion was based on a thin section of the Khohar meteorite[2], which contained chondrules consisting of enstatite with metallic rims. As this paper is not readily accessible in all libraries it is suitable to quote therefrom at some length in order to show the reason for the adoption of this hypothesis of the garnet origin of chondrules (*l. c.*, pp. 317-319):—

'The conversion of garnet to enstatite is easily explained by the following equation:—

$$\underset{\text{Garnet}}{3(Mg, Fe)O.Fe_2O_3.3SiO_2} = \underset{\text{Enstatite}}{3(Mg, Fe)SiO_3} + Fe_2O_3,$$

which requires an 8·5 per cent. increase in volume. The ferric oxide, expelled by the crystallising enstatite, was reduced by graphite (or some reducing gas) in the matrix of the original rock with formation of metallic iron according to the following equation:—

$$2Fe_2O_3 + 3C = 4Fe + 3CO_2$$

The reduction of pressure must have been sudden, enabling each garnet to liquefy under the influence of the prevalent high temperature. The sudden reduction of pressure must have been followed by a rapid decrease in temperature, causing the liquid globules to crystallise quickly with the production of the various

[1] *Journ. As. Soc. Bengal.* N. S., VIII, pp. 315-324, (1913): also *Proceedings*, p. cxxxiv, Sept. 1912.
[2] G. de P. Cotter, *Rec. Geol. Surv. Ind.*, XLII, p. 274 (1912).

radiated structures due to enstatite alone, and the complicated intergrowths resembling eutectic crystallisations, when both enstatite and olivine have crystallised out. Such a combination of conditions seems to me obtainable only in one way, namely by the sudden disruption of a celestial body in which lay, under high pressure and temperature at some depth below the surface, a garnetiferous zone analogous to the garnetiferous infra-plutonic zone of the earth. The sudden disruption of this celestial body would account for the sudden reduction of pressure promoting the liquefaction of the garnets. The dispersal of the fragments produced by this disruption would doubtless be accompained by a sufficiently speedy fall in temperature to cause the rapid congelation of the liquefied garnets.

Since it is possible to suggest this very simple explanation of the formations of chondrules, it is necessary to see whether such facts as are available support the idea. Returning to the original slide of the Khohar meteorite it is noticed that the degree of perfection of the iron-rim round each of the chondrules is very variable, and in some cases the iron is almost absent. This variation in the character of the iron border is to a certain extent correlative with variation in the character of the chondrules themselves. One particular chondrule of enstatite affords very convincing evidence. (See plate XXVII, fig. 2.) It is apparent from the slide that the enstatite has crystallised very rapidly, starting from a point on one side of the chondrules, and that, as the radiate needles of enstatite increased in length, they pushed before them the surplus ferric oxide. Consequently most of it occurs on the side of the chondrule remote from the point at which crystallisation started, not, however, as oxide, but in the metallic state, having been reduced outside the chondrule, probably by graphite in the matrix. A certain amount of the iron has become entangled between the enstatite needles, and indicates that there may have been inclusions of some form of carbon within the original garnet itself. The matrix of the rock between the chondrules consists largely of enstatite, olivine, and nickel-iron. These are to be regarded as original constituents of the rock as it existed in the primitive celestial body. When the pressure was released they suffered no appreciable change, except that the expansion of the garnets on liquefaction tended to produce brecciation of the rock, such brecciation being a common feature of chondritic meteorites. Other writers have noticed such metallic rims to chondrules, without explaining their occurrence[1]. As a result of the reaction given above, CO_2 (or CO) must have been formed. It is important to notice that both these gases are well known in meteorites.'

Although no other satisfactory solution of the origin of chondrules has been propounded, yet my suggestion has not met with general acceptance. Thus the late Dr. G. T. Prior was not able to accept this hypothesis because of his discovery[2]—

'that the proportion of nickel in the nickel-iron and that of ferrous oxide in the ferromagnesian silicates in meteorites are not independent variables, but are so related that in general *the richer in nickel is the nickel-iron the richer in ferrous oxide are the magnesian silicates*.

[1] *E.g.*, H. L. Bowman and H. E. Clarke, *Min. Mag.*, XV, D, in Fig. 3 of Plate IX, (1910). (The Chandakapur aerolite.)

[2] 'A Guide to the Collection of Meteorites', British Museum (Natural History), p. 19, (1926).

This reciprocal relation is, however, exactly what one would expect on my hypothesis, for the greater the amount of iron oxide expelled from the molten garnets on their crystallisation, with reduction to the metallic state, the larger would be the amount of iron added to the nickel-iron contents of the meteorite, with corresponding reduction of the proportion of nickel in the total nickel-iron.

An objection of another type is that of Shand[1], who remarks that the variable composition of the chondrules and the scarcity of alumina as compared with magnesia in chondritic meteorites seem to put this suggestion out of court. The reply to this is that garnets are notoriously variable in composition even within one rock[2], whilst the garnet invoked by me in this explanation is one with Fe_2O_3 as the sesquioxide radicle.

Since I propounded my hypothesis in 1912, no other has come to my notice that offers an explanation more plausible or as satisfactory, and consequently I still regard it as suitable to explain the formation of chondrules, and therefore of chondritic meteorites.

I have not previously drawn attention to the fact that the garnet adopted by me for this hypothesis is one that had not hitherto been introduced to science, consisting as it does of a mixture of two previously unrecognised garnet 'molecules'—$3MgO{\cdot}Fe_2O_3{\cdot}3SiO_2$ and $3FeO{\cdot}Fe_2O_3{\cdot}3SiO_2$—, which differ from pyrope and almandite respectively in that they contain Fe_2O_3 instead of Al_2O_3.

The second garnet 'molecule' $3FeO.Fe_2O_3.3SiO_2$ has since been detected as a constituent of certain Indian garnets (3 to 25 per cent.) and of a garnet ('spessartite') from Glen Skiag in Scotland (nearly 20 per cent.)[3], and named *skiagite* after the Scottish locality.

Recently it has seemed to me that if there is any foundation in fact to my garnet hypothesis of the origin of chondrules, I ought to be able to discover analyses of garnets that can be interpreted satisfactorily only on the assumption of the presence of a magnesia-iron garnet $3MgO.Fe_2O_3.3SiO_2$.

In such a search the presence of this 'molecule' can be accepted only after as much as possible of the Fe_2O_3 has been allocated to already accepted ferric garnets, namely andradite, $3CaO{\cdot}Fe_2O_3{\cdot}3SiO_2$, skiagite, $3FeO.Fe_2O_3.3SiO_2$, and calderite, $3MnO.Fe_2O_3.3SiO_2$.

[1] 'Eruptive Rocks', p. 300, (1927).

[2] A. Brammell and S. Bracewell, 'Variability of Garnet in Granites', *Min. Mag.*, XXIV, pp. 254-256, (1936).

[3] L. L. Fermor, *Rec. Geol. Surv. Ind.*, LIX, p. 202, (1926).

It is not surprising, therefore, that with this method of treating the problem it has proved difficult to identify $3MgO.Fe_2O_3.3SiO_2$. I have, however, found one occurrence, namely in an analysis of a deep brownish red garnet from a garnet-diopside nodule from the Jagersfontein diamond mine in South Africa, by the late Percy A. Wagner.[1] Dr. Wagner's analysis is as follows:—

——	Per cent.	Molecular Proportions.	Molecular Ratios.
SiO_2	40·79	0·6798	3·06
Al_2O_3	12·81	0·1256	1
Fe_2O_3	14·35	0·0897	
Cr_2O_3	1·03	0·0067	
FeO	7·39	0·1026	2·91
CaO	5·46	0·0975	
MgO	17·89	0·4472	
	99·72		

The closeness of this ratio 3·06 : 1 : 2·91 to the standard ratio for garnet, namely 3 : 1 : 3, is a testimony to the purity of the garnet and the accuracy of the analysis. There is no reason, therefore, for not accepting the result of the interpretation of this analysis in terms of garnet 'molecules', which is as follows:—

	Per cent.	
Pyrope	50·68	96·60 per cent. garnet.
Skiagite	19·06	
Andradite	13·14	
$3MgO.Fe_2O_3.3SiO_2$	10·36	
Uvarovite	3·36	
SiO_2	1·92	3·09 per cent. impurities.
Fe_2O_3	1·17	
	99·69	

[1] 'Die Diamantführenden Gesteine Sudafrikas', Berlin, p. 402, (1909).

We are compelled, therefore, to accept as proved the existence of the garnet 'molecule' $3MgO.Fe_2O_3.3SiO_2$ already deduced as present in the garnets from which chondrules have on my hypothesis been derived.[1] This new garnet needs a name. I should have liked to name it after the analyst, who did such brilliant work in South African geology before his early demise. This course is, however, prevented by another wagnerite, a monoclinic magnesium fluophosphate named as long ago as 1821 after an earlier, Oberbergrath, Wagner (see Dana). It is suitable that instead we should call this new garnet *khoharite*, after the meteorite for which it was first proposed.

II. THE NOMENCLATURE OF GARNETS.

a. Names of garnet 'molecules'.

As given in the usual text books of mineralogy there are six known garnet molecules conforming to the general formula $3R''O.R'''_2O_3.3SiO_2$. In four of these garnets R_2O_3 is alumina, in one of them it is ferric oxide, and in the sixth it is chromic oxide. There seems to be no reason based on the atomic dimensions of Al''', Fe''', Cr''' and Mn''' why there should not also be four ferric, four chromic, and four manganese garnets. In the past I have shown the existence of two additional ferric garnets (skiagite and calderite) and one manganic garnet (blythite)[2]; with the identification of khoharite it seems desirable to take stock of the position. The garnet 'molecules' now known, arranging them in order of increasing ionic radii of divalent and trivalent ions are:—

Alumina garnets—	
$3MgO.Al_2O_3.3SiO_2$	Pyrope.
$3FeO.Al_2O_3.3SiO_2$	Almandite.
$3MnO.Al_2O_3.3SiO_2$	Spessartite.
$3CaO.Al_2O_3.3SiO_2$	Grossularite.
Chromic garnets—	
$3CaO.Cr_2O_3.3SiO_2$	Uvarovite.
Ferric garnets—	
$3MgO.Fe_2O_3.3SiO_2$	Khoharite.
$3FeO.Fe_2O_3.3SiO_2$	Skiagite.
$3MnO.Fe_2O_3.3SiO_2$	Calderite.
$3CaO.Fe_2O_3.3SiO_2$	Andradite.
Manganic garnets—	
$3MnO.Mn_2O_3.3SiO_2$	Blythite.

[1] The alternative is to assume an error of 2·72 per cent. surplus in the determination of magnesia and the presence of 13·46 per cent. of impurities or included minerals instead of 3·09 per cent.

[2] 'On the Composition of some Indian Garnets', *Rec. Geol. Surv. Ind.*, LIX, pp. 191-207, (1926): p. 202 for skiagite and p. 204 for calderite and blythite.

It will be seen from the foregoing statement that there are three manganic and three chromic garnet 'molecules' still undiscovered, but all possible, judging from the atomic structures of garnets. Whether the facts of Nature provide for their occurrence anywhere is another matter.

b. Names for compound garnets.

In speaking of garnet 'molecules' and of R_2O_3 groups I have, of course, been using the old nomenclature, and have been referring to the composition of garnets in terms of the results of their chemical analysis. X-ray studies of garnets show, however, that they do not contain the R_2O_3 group as such, and, moreover, that the complete unit cell of garnet is eight times the traditional formula or 'molecule', so that strictly speaking the formula of garnet should be written as—

$$8[R''_3R'''_2(SiO_4)_3],$$

the unit cell of garnet containing 24 atoms of divalent metals, 16 atoms of trivalent metals, 24 atoms of silicon, and 96 atoms of oxygen, 160 atoms in all. The silicon and oxygen are combined in groups of SiO_4, because X-ray analysis shows that each silicon atom is the centre of a tetrahedron of oxygen atoms, the other elements being linked to these oxygen atoms.

As no pure garnet has ever been found, it must be very rarely, if ever, in Nature that a unit cell of garnet contains only one divalent or only one trivalent element. A garnet that on analysis is found to contain say 50 per cent. of pyrope and 50 per cent. of almandite must not be pictured as a mixture of unit cells, some with only Mg and some with only Fe″ as the divalent metal; instead, it must be pictured as composed of unit cells each of which contains (on the average) 12 Mg atoms and 12 Fe″ atoms. Consequently, when it is desired to express by one formula the composition of such a garnet it is desirable to use some such form as

$$Mg_{12}Fe''_{12}Al_{16}(SiO_4)_{24},$$

the ratios of the divalent elements being referred to 24 and of the trivalent elements to 16.

In my Memoir on the Manganese-Ore Deposits of India published in 1909[1] I proposed the term *spandite* (as an abbreviation

[1] *Mem. Geol. Surv. Ind.*, XXXVII, pp. 163-165.

of spessart-andradite) for a garnet intermediate in composition between spessartite and andradite; and *grandite* for a garnet intermediate between grossularite and andradite. Later, in the 1926 paper to which reference has been made above, I used the terms *pyralmandite* and *spalmandite* for garnets intermediate between pyrope and almandite and spessartite and almandite respectively. In following this course it seems that I was adopting one that the facts of crystal structure have since proved to be justified. Thus spandite, instead of being a mere mixture of spessartite and andradite molecules in solid solution, must be a garnet in which the unit cell contains both Mn and Ca as divalent atoms and Al and Fe''' as trivalent atoms: and so on for the other garnets named.

The above course was advocated only when each of the two garnet 'molecules' included in the name was in large proportion. To indicate the presence of constituents in less important proportion I suggested the use of chemical prefixes as in *mangan-grandite*[1], *mangan-almandite, ferro-spessartite, calc-spessartite* and *magnesia-blythite*[2]. We see now that such a term as ferro-spessartite means a spessartite with some of the Mn'' (or Al''') atoms replaced by Fe'' (or Fe''') in the unit cell, and that such a term must correspond to a real entity. Similarly mangan-grandite is a garnet with a proportion of the divalent Ca atoms in one unit cell replaced by Mn atoms and with both Al and Fe''' occupying the spaces for trivalent elements.

On page 205 of the 1936 paper cited above I give the formulæ of five analysed garnets in terms of percentages of constituent garnet molecules. Thus spandite is given as—

$$Py_7Sp_{23}An_{47}Sk_5Ca_{17},$$

the five symbols standing for pyrope, spessartite, andradite, skiagite, and calderite respectively. The information this was intended to convey was that this garnet consisted of five garnet 'molecules' isomorphously mixed in the proportions shown. The revised method of looking at this garnet is that it consists of unit cells each with the following approximate composition:

$$Ca_{11}Mn_{10}Mg_2Fe''_1Fe'''_{11}Al_5(SiO_4)_{24},$$

[1] *Mem. Geol. Surv. Ind.*, XXXVII, p. 164, (1909).
[2] *Rec. Geol. Surv. Ind.*, LIX, pp. 202-206, (1926).

and this is the approximate composition of the spandite analysed. The extent to which the percentage proportions of the garnet 'molecules' cannot be adjusted to integral fractions of 24 for the divalent atoms and of 16 for the trivalent atoms must be regarded, in so far as it is not due to experimental error, as a measure of slight variation from the composition of one unit cell of garnet to another in the same specimen.

Although the second method of representing the analysis of spandite given above shows a closer relationship to the intimate facts of Nature than the first, yet this first method will no doubt still often be used in order to show the statistical proportions of the imaginary constituent 'molecules', which are in all probability rarely present!

My method of conjoining portions of the names of garnets to represent a compound garnet has been adopted by A. N. Winchell[1]. Making use of the work of Boeke[2], who showed that, based on a study of analysed garnets, there appear to be limits to the mutual solubilities of the six garnets commonly recognised, so that they can be grouped into two sets or types, each mutually soluble, Winchell applies the term *pyralspite* to the set pyrope, almandite and spessartite, and *ugrandite* to the set uvarovite, grossularite and andradite. Within each set there is supposed to be complete mutual solubility. The data do indicate that this is the case for spessartite and almandite and probably for pyrope and almandite; but there are no analytical data indicating the complete mutual solubility of spessartite and pyrope, and Winchell's pyralspite appears to be a statistical amalgamation of my pyralmandite and spalmandite. His ugrandite is composed mainly of grossularite and andradite, as is recognised in the compositional diagram reproduced from Boeke where the term 'grandite' is wrongly used[3]. Whether this grouping of garnet into two sets under the terms pyralspite and ugrandite is useful depends really upon whether we need names to described groups or series of garnets instead of actual garnets, and whether it is desirable to take any

[1] 'Elements of Optical Mineralogy', 2nd Edit., Part II, pp. 257-265, (1927).

[2] 'Die Granatgruppe', *Zeit. Kryst.*, LIII, pp. 149-157, (1913).

[3] 'Grandite' was proposed by me to describe garnets containing important proportions of grossularite and andradite, and is not therefore available for use as a name for either grossularite or andradite alone. There seems, however, to be no objection to referring to the three garnets grossularite, grandite, and andradite, as the *grandite series*, any more than there would be in referring to spessarite, spandite, and andradite, as the *spandite series*.

notice of the other four garnet 'molecules' detected by me, which, though usually absent or rare, are sometimes present in notable proportions.

Boeke's diagram of variation in the composition of garnets has been arrived at by plotting analyses. It expresses, therefore, a statistical fact, namely that the majority of garnets can be grouped into two sets or series. The question is whether this is due to the

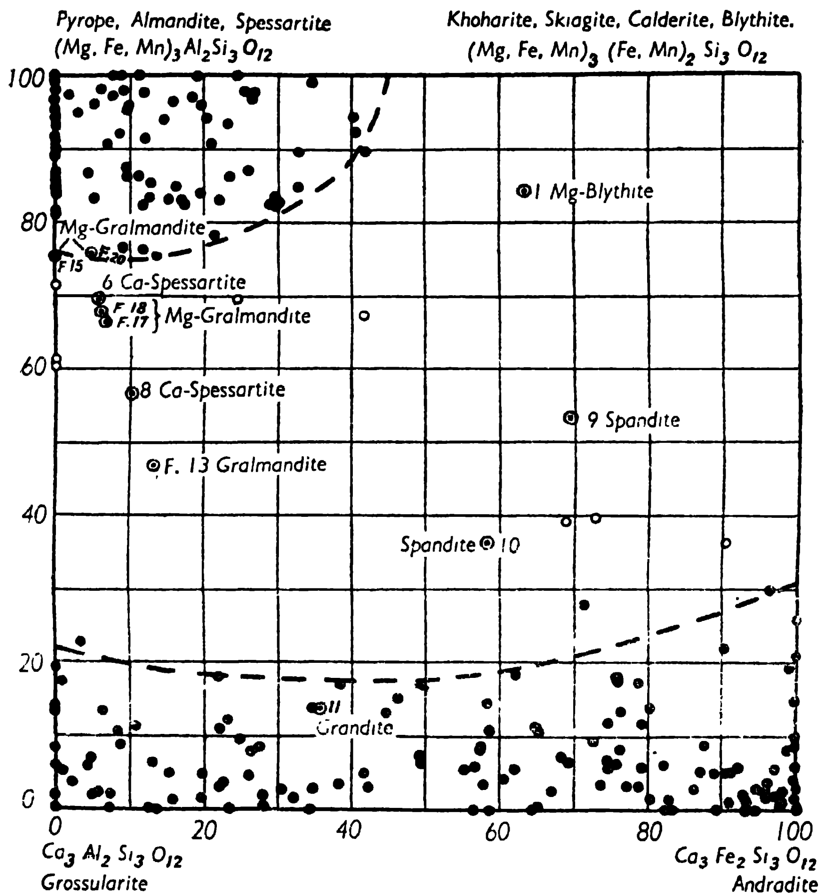

Fig. 1. Variations in composition of garnet after Boeke, *Zeit, Kryst.*, LIII, p. 149. (1914).

inherent physical properties of garnets rendering impossible the existence of 'mixtures' occupying the field between 'pyralspite' and 'ugrandite', or is merely due to the opportunities of association of the various elements usually provided by Nature. Boeke's diagram does in fact show several garnets occupying this intermediate terrain; but the author discusses each of these exceptions in turn and gives reasons (impurities, imperfect analysis, etc.), for rejecting them.

I have, however, myself published analyses of several garnets that fall well into the terrain between 'pyralspite' and 'ugrandite'[1]. Referring to the table on page 341 of the paper cited, the garnets from Chargaon (magnesia-blythite), Sakrasanhalli (calc-spessartite), Kotakarra (calc-spessartite), Garbham (spandite), and Kodur (spandite), all fall well into this terrain, and there seems to be little doubt that complete solubility exist between some portions at least of the 'pyralspite' group and some portions at least of the 'ugrandite' group, and particularly between spessartite and andradite; and that there is a manganese-lime series of garnets cutting diagonally across Boeke's diagram from north-west to south-east. Boeke's diagram is reproduced here with the addition of six spots corresponding in numbers to six analyses in my own paper, of five spots corresponding to five analyses in Fleischer's paper, but distinguished by the letter F. In addition there is a high degree of mutual solubility between almandite and grossularite, as instanced by analyses Nos. 13 (gralmandite) and 25, 20, 15, 21, 17 and 18 (magnesia-gralmandite) of M. Fleischer's recent paper[2], and by the analyses by N. Jayaram of Nellore garnets[3]. The six Nellore garnets contain 8·55 to 18·52 per cent. of grossularite, 7·50 to 21·10 per cent. of pyrope, and 56·72 to 64·72 per cent. of almandite; and as a group they may be described as calc-pyralmandites and magnesia-gralmandites according to the relative proportions of pyrope and grossularite. Analysis No. 13 of Fleischer's paper reveals the presence of 53·56 per cent. of garnets of the 'pyralspite' series and 46·43 per cent. of the 'ugrandite' series. It seems certain in fact that besides the 'pyralspite' series and the 'ugrandite' series that there are a

[1] 'Note on the Manganese-Lime Series of Garnets', *Rec. Geol. Surv. Ind.*, LXVIII, pp. 337-343, (1934).

[2] 'The relation between chemical composition and physical properties in the garnet group', *Amer. Min.*, Vol. 22, p. 754, (1937).

[3] 'The mineralogy and chemical composition of garnets from the schist-complex of Nellore' *Proc. Ind. Acad. Sci.*, V, Sec. A, pp. 148-160, (1937).

spandite series and a gralmandite series cutting across the space between the two former series. Further, amongst the garnet analyses listed by Fleischer there is not one which represents a garnet to which either of the terms pyralspite or ugrandite could be applied on a basis that required the presence of a minimum of 10 per cent. of a constituent for recognition in the name.

Other garnets that fall outside the fields of 'pyralspite' and 'ugrandite' are the three ferric garnets khoharite, skiagite, and calderite, which occupy the north-east corner of the diagram, the position also for blythite if manganic garnets be grouped with the ferric garnets.

Further, the atomic structure of garnet does not appear to supply any structural reason for the supposed limited solubilities between the two chief groups statistically detected by Boeke. All the garnets belong to the space-group O_n^{10} or I_m3_m which is the space-group of the highest degree of symmetry amongst the 230 possible groups. It is true that the physical properties of garnets—refractive index and specific gravity for instance—vary with their composition, as has been well shown by W. E. Ford[1] and M. Fleischer[2], but these variations are merely the result of variation in the proportions of the various divalent and trivalent atoms in the space lattice. There seems to be no reason based on the size of these atoms why any particular association or 'admixture' should be physically incompatible with the garnet structure.

And as we have the fact of two series of garnets, the manganese-lime garnets (spandite series), and the lime-iron garnets (gralmandite series), cutting right across the space between 'pyralspite' and 'ugrandite' in Boeke's diagram, it seems more logical to assume that the infrequency of garnets the analyses of which occupy this space is a reflection of the limited opportunities provided by Nature based on the proportions of the elements available for forming garnets, rather than of any inherent difficulty based on the atomic structure of garnet and the physical properties dependent thereon.

In order to illustrate the suitability or otherwise of using hybrid and hyphenated names for garnets we may apply the methods noticed in this paper to the batch of analyses of garnets, 57 in number, collected in Fleischer's paper to which reference has been made above, adopting as a rough limit that a minimum of 10 per cent.

[1] *Amer. Journ. Sci.*, Vol. 40, pp. 33-49, (1915).
[2] *Amer. Min.*, Vol. 22, pp. 751-759, (1937).

of a garnet should be present to warrant recognition in the name, and that of those above this limit the two major garnets should be conjoined in the name, and the third (if important enough) should be recognised by a chemical prefix:—

	Number of analyses.
Pyrope	*Nil.*
Almandite	35, 50, 44.
Pyralmandite	41, 32, 36, 29, 19, 10, 12.
Calc-pyralmandite	33, 27, 16, 14, 11, 9, 5.
Spalmandite	51, 49, 48, 46, 47, 43, 34, 42, 22, 38, 45, 37, 31, 40.
Spessartite	24, 28.
Ferro-spessartite	23, 39, 30.
Grossularite	2, 1, 4, 8.
Gralmandite	13.
Magnesia-gralmandite	25, 20, 15, 21, 17, 18.
Manganese-gralmandite	26.
Andradite	55, 57.
Grandite	3, 6, 7, 54.
Spandite	56.
Uvarovite	53, 52.

These names do not, of course, possess any quantitative significance. Thus the garnets included above under spalmandite range from No. 51, with 75·00 per cent. of almandite and 15·63 per cent. of spessarite, to No. 40, with 29·24 per cent. of almandite and 69·35 per cent. of spessartite; whilst under grandite we have No. 3, with 83·96 per cent. of grossularite and 10·80 per cent. of andradite, and No. 54, with 17·05 per cent. of grossularite and 73·70 per cent. of andradite.

In this discussion on the nomenclature of garnets I have not thought it necessary to discuss schorlomite, which is treated by Dana as a separate mineral from garnet with the formula $3CaO.(Fe,Ti)_2O_3.3(Si,Ti)O_2$, from which, combined with the fact that garnet is isometric, it seems that we may regard schorlomite as a titaniferous andradite, which has this peculiarity, judging from the analyses of specimens from Magnet Cove given by Dana, that it is freer from the presence of other garnet 'molecules' than most garnets.

It has also seemed unnecessary to discuss varietal names such as polyadelphite, rhodolite, and topazolite, applied to garnets from particular localities.

PROVISIONAL STATISTICS OF SOME OF THE MORE IMPORTANT INDIAN MINERALS FOR 1937. BY A. M. HERON, D.Sc., F.G.S., F.R.G.S., F.R.S.E., F.R.A.S.B., *Director, Geological Survey of India.*

"The Mineral Production of India" is compiled annually in August for the previous year and is published, usually in October, in Part 3 of the *Records* of the Geological Survey of India.

Owing to the very varied sources from which these statistics are derived and the delays, not attributable to the Geological Survey of India, in obtaining them, it has been found impossible to produce this detailed review earlier in the year. It has, however, been felt that a less complete and less accurate but substantially earlier issue of statistics relating to a few of the more important minerals produced in India would be of interest to the public.

These figures must be considered as provisional and partial only; the revised and complete statistics will be issued as usual in Part 3 of this volume. The figures in brackets give the final productions for 1936.

Antimonial lead . . The production by the Burma Corporation Ltd., amounted to 1,150 tons in 1937. (1,240 tons). This product contains 81·66 per cent. of lead, 17·69 per cent. of antimony, 0·21 per cent. of copper and 3·44 ozs. of silver to the ton.

Chromite . . . . The production in Bihar amounted to 6,197 tons, (7,053 tons), in Baluchistan 27,209 tons, (21,089 tons), and in Mysore State 26,013 tons, (21,344 tons).

Coal . . . . . 22,313,205 tons of coal were raised from the coal mines worked under the Indian Mines Act. (20,585,691 tons).

Cobalt . . . . See Nickel Speiss.

Copper . . .	The production of copper-ore by the Indian Copper Corporation Ltd. amounted to 371,458 tons (357,194 tons). A total of 374,742 short tons (348,375 short tons) of ore was treated in the mill and the production of refined copper amounted to 6,830 long tons (7,200 long tons).
Copper matte. . .	7,750 tons were produced by the Burma Corporation Ltd. (7,500 tons).
Gold	330,690 ozs. of gold were produced from the Kolar goldfields in Mysore during 1937. (331,856·1 ozs.). The production from the operations of the Burma Corporation Ltd., at Bawdwin, Burma, amounted to 894 ozs. (1,294 ozs.).
Ilmenite . . .	The production in Travancore State amounted to 181,047 tons (140,477 tons).
Iron	2,522,750 tons of iron-ore were produced by the principal mining companies in Bihar and the Eastern States Agency. (2,484,445 tons). The production by the Burma Corporation Ltd. from their mines at Wetwun, near Maymyo, Burma, amounted to 25,426 tons. (26,316 tons). This is used as a flux in smelting lead.
Lead	The production of lead-ore at the Burma Corporation's Bawdwin mines in Burma amounted to 476,896 tons (468,842 tons); the total amount of metal extracted was 77,650 tons (73,155 tons) including 1,150 tons (1,240 tons) of antimonial lead.
Magnesite . . .	The production of calcined magnesite by the Salem Magnesite Syndicate, Ltd., Salem, Madras, amounted to 10,339 tons. (12,966 tons). The production in Mysore State amounted to 2,384 tons (2,502 tons).
Manganese-ore . .	978,193 tons were produced during the year. (813,442 tons).

Mica	297,343 cwts. of mica, including splittings, were exported from India during the year. (177,664 cwts.).
Monazite . . .	The production in Travancore State amounted to 3,081 tons. (2,628 tons).
Nickel speiss . .	The production by the Burma Corporation Ltd. amounted to 4,020 tons (4,325 tons). This product contains 30·20 per cent. of nickel, 8·94 per cent. of copper, 6·81 per cent. of cobalt and 17·7 ozs. of silver to the ton.
Petroleum . . .	The production in Assam amounted to 65,718,437 gallons, (64,844,712 gallons), in the Punjab 10,026,560 gallons, (4,396,792 gallons) and in Burma 273,807,738 gallons. (265,570,120 gallons).
Salt	The production of salt amounted to 1,898,157 tons, (1,735,888 tons) including 53,813 tons in Burma and 355,166 tons in Aden.
Saltpetre . . .	167,147 cwts. were exported from India during the year (162,808 cwts.).
Silver	The production of silver from the Burma Corporation Ltd. Bawdwin mines amounted to 6,180,000 ozs. (5,952,000 ozs.) and that from the Kolar gold mines in Mysore State 28,959 ozs. (estimated). (24,477 ozs.).
Tin concentrates . .	5,173 tons were produced in Burma including Karenni and Mong Pai States. (6,498·8 tons).
Tungsten concentrates .	3,028 tons were produced in Burma including Karenni and Mong Pai States. (4,562·0 tons).
Zinc concentrates .	73,552 tons were produced by the Burma Corporation Ltd., from their mines at Bawdwin, Burma. (76,807 tons).
Zircon . . .	The production in Travancore State amounted to 1,225 tons. (2,209·9 tons).

MISCELLANEOUS NOTE.

Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma: October to December, 1937.

Coal.

	October.	November.	December.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	18,062	18,653	21,088	57,803
Baluchistan	795	917	738	2,450
Bengal	575,767	472,691	642,096	1,690,554
Bihar	1,203,569	1,056,166	1,348,699	3,608,434
Orissa	5,412	3,935	3,706	13,053
Central Provinces	120,037	108,390	151,077	379,504
Punjab	14,979	16,102	15,184	46,265
TOTAL	1,938,621	1,676,854	2,182,588	5,798,063

Gold.

	October.	November.	December.	Quarterly total for each Company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	8,203	7,937	9,581	25,721
The Champion Reef Gold Mines India, Ltd.	5,898	5,715	6,436	18,049
The Ooregum Gold Mining Company of India, Ltd.	4,121	4,209	4,152	12,482
The Nundydroog Mines, Ltd.	9,234	8,951	9,217	27,402
TOTAL	27,456	26,812	29,386	83,654

Petroleum.

	Crude Petroleum.	Total gasolene from natural gas.*
	Gallons.	Gallons.
Assam	16,439,569	..
Burma	71,154,556	2,603,352
Punjab	4,422,120	96,583
TOTAL .	92,016,245	2,699,935

* These figures represent the total amounts of gasolene derived from natural gas at the well-head. Of these amounts a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries. The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous *Records*.

A. M. HERON.

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RECORDS OF THE GEOLOGICAL SURVEY OF INDIA.

VOL. I, 1868.

Part 1 (out of print).—Annual report for 1867. Coal-seams of Tawa valley. Coal in Garrow Hills. Copper in Bundelkhund. Meteorites.

Part 2 (out of print).—Coal-seams of neighbourhood of Chanda. Coal near Nagpur. Geological notes on Surat collectorate. Cephalopodous fauna of South Indian cretaceous deposits. Lead in Raipur district. Coal in Eastern Hemisphere. Meteorites.

Part 3 (out of print).—Gastropodous fauna of South Indian cretaceous deposits. Notes on route from Poona to Nagpur *viâ* Ahmednuggur, Jalna, Loonar, Yeotmahal, Mangali and Hingunghat. Agaté-flake in pliocene (?) deposits of Upper Godavary. Boundary of Vindhyan series in Rajputana. Meteorites.

VOL. II, 1869.

Part 1 (out of print).—Valley of Poorna river, West Berar. Kuddapah and Kurnool formations. Geological sketch of Shillong plateau. Gold in Singhbhum, etc. Wells at Hazareebagh. Meteorites.

Part 2 (out of print).—Annual report for 1868. Pangshura tecta and other species of Chelonia from newer tertiary deposits of Norbudda valley. Metamorphic rocks of Bengal.

Part 3 (out of print).—Geology of Kutch, Western India. Geology and physical geography of Nicobar Islands.

Part 4 (out of print).—Beds containing silicified wood in Eastern Prome, British Burma. Mineralogical statistics of Kumaon division. Coal-field near Chanda. Lead in Raipur district. Meteorites.

VOL. III, 1870.

Part 1 (out of print).—Annual report for 1869. Geology of neighbourhood of Madras. Alluvial deposits of Irrawadi, contrasted with those of Ganges.

Part 2 (out of print).—Geology of Gwalior and vicinity. Slates at Chiteli, Kumaon. Lead vein near Chicholi, Raipur district. Wardha river coal-fields, Berar and Central Provinces. Coal at Karba in Bilaspur district.

Part 3 (out of print).—Mohpani coal-field. Lead-ore at Slimanabad, Jabalpur district. Coal, east of Chhattisgarh between Bilaspur and Ranchi. Petroleum in Burma. Petroleum locality of Sudkal, near Futtijung, west of Rawalpindi. Argentiferous galena and copper in Manbhum. Assays of iron ores.

Part 4 (out of print).—Geology of Mount Tilla, Punjab. Copper deposits of Dalbhum and Singhbhum: 1.—Copper mines of Singhbhum: 2.—Copper of Dalbhum and Singhbhum. Meteorites.

VOL. IV, 1871.

Part 1 (out of print).—Annual report for 1870. Alleged discovery of coal near Gooty, and of indications of coal in Cuddapah district. Mineral statistics of Kumaon division.

Part 2 (out of print).—Axial group in Western Prome. Geological structure of Southern Konkan. Supposed occurrence of native antimony in the Straits Settlements. Deposit in boilers of steam-engines at Raniganj. Plant-bearing sandstones of Godavari valley, on southern extensions of Kamthi group to neighbourhood of Ellore and Rajmandri, and on possible occurrence of coal in same direction.

Part 3 (out of print).—Borings for coal in Godavari valley near Dumagudem and Bhadrachalam. Narbada coal-basin. Geology of Central Provinces. Plant-bearing sandstones of Godavari valley.

Part 4 (out of print).—Ammonite fauna of Kutch. Raipur and Hengir (Gangpur) Coal-field. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

VOL. V, 1872.

Part 1 (out of print).—Annual report for 1871. Relations of rocks near Murree (Mari), Punjab. Mineralogical notes on gneiss of South Mirzapur and adjoining country. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Part 2 (out of print).—Coasts of Baluchistan and Persia from Karachi to head of Persian Gulf, and some of Gulf Islands. Parts of Kummummet and Hanamconda districts in Nizam's Dominions. Geology of Orissa. New coal-field in south-eastern Hyderabad (Deccan) territory.

Part 3 (out of print).—Maskat and Massandim on east of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.

Part 4 (out of print).—Coal in northern region of Satpura basin. Evidence afforded by raised oyster banks on coasts of India, in estimating amount of elevation indicated thereby. Possible field of coal-measures in Godavari district, Madras Presidency. Lameta or intra-trappean formation of Central India. Petroleum localities in Pegu. Supposed eozoonal limestone of Yellam Bile.

VOL. VI, 1873.

Part 1.—Annual report for 1872. Geology of North-West Provinces.

Part 2 (out of print).—Bisrampur coal-field. Mineralogical notes on gneiss of south Mirzapur and adjoining country.

Part 3 (out of print).—Celt in ossiferous deposits of Narbada valley (Pliocene of Falconer): on age of deposits, and on associated shells. Barakars (coal-measures) in Beddadanole field, Godavari district. Geology of parts of Upper Punjab. Coal in India. Salt-springs of Pegu.

Part 4 (out of print).—Iron deposits of Chanda (Central Provinces). Barren Islands and Narkondam. Metalliferous resources of British Burma.

VOL. VII, 1874.

Part 1 (out of print)—Annual report for 1873. Hill ranges between Indus valley in Ladak and Shah-i-Dula on frontier of Yarkand territory. Iron ores of Kumaon. Raw materials for iron-smelting in Raniganj field. Elastic sandstone, or so-called Itacolumyte. Geological notes on part of Northern Hazaribagh.

Part 2 (out of print).—Geological notes on route traversed by Yarkand Embassy from Shah-i-Dula to Yarkand and Kashgar. Jade in Karakash valley, Turkistan. Notes from Eastern Himalaya. Petroleum in Assam. Coal in Garo Hills. Copper in Narbada valley. Potash-salt from East India. Geology of neighbourhood of Mari hill station in Punjab.

Part 3 (out of print).—Geological observations made on a visit to Chadderkul, Thian Shan range. Former extension of glaciers within Kangra district. Building and ornamental stones of India. Materials for iron manufacture in Raniganj coal-field. Manganese-ore in Wardha coal-field.

Part 4 (out of print).—Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

VOL. VIII, 1875.

Part 1 (out of print).—Annual report for 1874. The Altum-Artush considered from geological point of view. Evidences of 'ground-ice' in tropical India, during Talchir period. Trials of Raniganj fire-bricks.

Part 2 (out of print).—Gold-fields of south-east Wynaad, Madras Presidency. Geological notes on Khareean hills in Upper Punjab. Water-bearing strata of Surat district. Geology of Scindia's territories.

Part 3 (out of print).—Shahpur coal-field, with notice of coal explorations in Narbada regions. Coal recently found near Moflong, Khasia Hills.

Part 4 (out of print).—Geology of Nepal. Raigarh and Hingir coal-fields.

VOL. IX, 1876.

Part 1 (out of print).—Annual report for 1875. Geology of Sind.

Part 2 (out of print).—Retirement of Dr. Oldham. Age of some fossil floras of India. Cranium of Stegodon Ganesa, with notes on sub-genus and allied forms. Sub-Himalayan series in Jamu (Jammoo) Hills.

Part 3 (out of print).—Fossil floras in India. Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Maleri and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.
Part 4 (out of print).—Fossil floras in India. Osteology of Meryoopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

Vol. X, 1877.

Part 1 (out of print).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheira in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Embydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.
Part 2 (out of print).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.
Part 3 (out of print).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.
Part 4 (out of print).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis', McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'
Part 2 (out of print).—Geology of Sind (second notice). Origin of Kumaon lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.
Part 3 (out of print).—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.
Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1 (out of print).—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia. Siwalik beds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.
Part 2 (out of print).—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.
Part 3 (out of print).—Geological features of northern Madura, Pudukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia speciosa, Royle (Sphenophyllum trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbudda.
Part 4.—"Attock Slates" and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1 (out of print).—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of North-Eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas'. Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain: and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danaite from Khetri mines, Rajputana; with remarks on Jaipurite (Syepoorite). Zinc-ore (Smithsonite and Blende) with barytes in Karnul district, Madras. Mud-eruption in island of Cheduba.

Part 3 (out of print)—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Unification of geological nomenclature and cartography. Geology of Arvali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah district, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district; (2) arsenical pyrites in same neighbourhood; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Gold-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kays (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosalpore, Jabalpur district. Umaria coal-field.

Part 3 (out of print).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussooree. Cretaceous coal-measures at Borsora in Khasia Hills, near Laour in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

VOL. XVII, 1884.

Part 1 (out of print).—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Kurnool district. Geology of Chuari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (out of print).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (out of print).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishâpûr, Khorassan. Fiery eruption from Mynbyin mud volcano of Cheduba Island, Arakan. Langrin coal-field, South-West Khasia Hills. Umaria coal-field.

Part 4 (out of print).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

VOL. XVIII, 1885.

Part 1 (out of print).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2 (out of print).—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (out of print).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthalla and Chandpur meteorites. Oil wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmain district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (out of print).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

VOL. XIX, 1886.

Part 1 (out of print).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field notes. Section from Simla to Wangtu, and petrological character of Amphibolites and Quartz-Diorites of Sutlej valley.

Part 2 (out of print).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruption rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-note from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2 (out of print).—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west, of Salt-range, in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Woolasten Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888 Dharwar System in South India. Wajra Karur diamonds, and M Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-fields, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputaná. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part I.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicyonodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive-group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal fields of Lairungao, Meosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1 (out of print).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-spring near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (out of print).—Mammalian Bones from Mongolia. Darjiling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1 (out of print).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dasht-i-Bedaiot; with appendices on Chammans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Saléd Kôh. Jherria Coal-field

Part 3 (out of print).—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (out of print).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Ambar-like Resin in Burma. Triassic Deposits of Salt-range.

Vol. XXVI, 1893.

Part 1 (out of print).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma, Burmite, new Fossil Resin from Upper Burma. Prospecting Operations. Mergui District, 1891-92.

Part 2 (out of print).—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (out of print).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4 (out of print).—Geology of country between Chappar Rift and Harnai in Baluchistan. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

Vol. XXVII, 1894.

Part 1 (out of print).—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.
Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.
Part 3 (out of print).—Cambrian Formation of Eastern Salt-range. Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.
Part 4 (out of print).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistan. Highly Phosphatic Mica Periodotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Periodotite in Bengal.

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.
Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.
Part 3 (out of print).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.
Part 4 (out of print).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyans. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

Vol. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.
Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwana-land." Notes.
Part 3.—Igneous Rocks from the Tochi Valley. Notes.
Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

Vol. XXX, 1897.

Part 1 (out of print).—Annual report for 1896. Norite and associated Basic Dykes and Lava flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.
Part 2.—Cretaceous Deposits of Pondicherri. Notes.
Part 3 (out of print).—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikaner. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.
Part 4 (out of print).—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Caut. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

Vol. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjiling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.
Part 2 (out of print).—Lt.-Genl. C. A. MacMahon. Cyclobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.
Part 3 (out of print).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.
Part 4 (out of print).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

Vol. XXXII, 1905.

Part 1.—Review of Mineral Production of India during 1898-1903.

Part 2 (*out of print*).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and U in Tibet. Bauxite in India. Miscellaneous Notes.

Part 3 (*out of print*).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites-Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.

Part 4.—Obituary notices of H. B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

Vol. XXXIII, 1906.

Part 1 (*out of print*).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.

Part 2 (*out of print*).—General report for 1905. Lashio Coal-field, Northern Shan States. Namma, Mansang and Man-se-le Coal-fields, Northern Shan States, Burma. Miscellaneous Notes.

Part 3 (*out of print*).—Petrology and Manganese-ore Deposits of Sausar Tahsil, Chhindwara district, Central Provinces. Geology of part of valley of Kanhan River in Nagpur and Chhindwara districts, Central Provinces. Manganite from Sandur Hills. Miscellaneous Notes.

Part 4 (*out of print*).—Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond-bearing Deposits. Index to Volume XXXIII.

Vol. XXXIV, 1906.

Part 1 (*out of print*).—Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan. Coal Occurrences in Foot-hills of Bhutan. Dandli Coal-field: Coal outcrops in Kotli Tahsil of Jammu State. Miscellaneous Notes.

Part 2 (*out of print*).—Mineral production of India during 1905. Nummulites Douvillei, with remarks on Zonal Distribution of Indian Nummulites. Auriferous Tracts in Southern India. Abandonment of Collieries at Warora, Central Provinces. Miscellaneous Notes.

Part 3 (*out of print*).—Explosion Craters in Lower Chindwin District, Burma. Lavas of Pavagad Hill. Gibbsite with Manganese-ore from Talevadi, Belgaum district, and Gibbsite from Bhekowli, Satara District. Classification of Tertiary System in Sind with reference to Zonal Distribution of Eocene Echinoidea.

Part 4 (*out of print*).—Jaipur and Nazira Coal-fields, Upper Assam. Makum Coal-fields between Tirap and Namdang Streams. Kobat Anticline, near Seiktein, Myingyan district, Upper Burma. Asymmetry of Yenangyat-Singu Anticline, Upper Burma. Northern part of Gwegyo Anticline, Myingyan District, Upper Burma. Breynia Multituberculata, from Nari of Baluchistan and Sind. Index to Volume XXXIV.

Vol. XXXV, 1907.

Part 1 (*out of print*).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokachi and neighbourhood, Dacca district.

Part 2 (*out of print*).—Indian Aerolites. Brine-wells at Bawgyo, Northern Shan States. Gold-bearing Deposits of Loi Twang, Shan States. Physa Prinsepii in Maestrichtian strata of Baluchistan. Miscellaneous Notes.

Part 3.—Preliminary survey of certain Glaciers in North-West Himalaya. A.—Notes on certain Glaciers in North-West Kashmir.

Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

Vol. XXXVI, 1907-08

Part 1 (*out of print*).—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic outburst of Late Tertiary Age in South Hsenwi, N. Shan States. New suidæ from Bugti Hills, Baluchistan, Permo-Carboniferous Plants from Kashmir.

Part 2 (out of print).—Mineral Production of India during 1906. Ammonites of Bagh Beds. Miscellaneous Notes.

Part 3 (out of print).—Marine fossils in Yenangyaung oil-field, Upper Burma. Freshwater shells of genus Batissa in Yenangyaung oil-field, Upper Burma. New Species of Dendrophyllia from Upper Miocene of Burma. Structure and age of Taungtha hills, Myingyan district, Upper Burma. Fossils from Sedimentary rocks of Oman (Arabia). Rubies in Kachin hills, Upper Burma. Cretaceous Orbitoides of India. Two Calcutta Earthquakes of 1906. Miscellaneous Notes.

Part 4 (out of print).—Pseudo-Fucoids from Pab sandstones at Fort Munro, and from Vindhyan series. Jadeite in Kachin Hills, Upper Burma. Wetchok-Yedwet Pegu outcrop, Magwe district, Upper Burma. Group of Manganates, comprising Hollandite, Psilomelane and Coronadite. Occurrence of Wolfram in Nagpur district, Central Provinces. Miscellaneous Notes. Index to Volume XXXVI.

Vol. XXXVII, 1908-09.

Part 1 (out of print).—General report for 1907. Mineral Production of India during 1907. Occurrence of striated boulders in Blaini formation of Simla. Miscellaneous Notes.

Part 2 (out of print).—Tertiary and Post-Tertiary Freshwater Deposits of Baluchistan and Sind. Geology and Mineral Resources of Rajpipla State. Suitability of sands in Rajmahal Hills for glass manufacture. Three new Manganese-bearing minerals:—Vredenburgite, Sitaparite and Juddite. Laterites from Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Southern part of Gwegyo Hills, including Payagyigon-Ngashandaung Oil-field. Silver-lead mines of Bawdwin, Northern Shan States. Mud volcanoes of Arakan Coast, Burma.

Part 4.—Gypsum Deposits in Hamirpur district, United Provinces. Gondwanas and related marine sedimentary system of Kashmir. Miscellaneous Notes. Index to Volume XXXVII.

Vol. XXXVIII, 1909-10.

Part 1.—General report for 1908. Mineral Production of India during 1908.

Part 2 (out of print).—Ostrea latimarginata in "Yenangyaung stage" of Burma. China-clay and Fire-clay deposits in Rajmahal Hills. Coal at Gilhurria in Rajmahal hills. Pegu Inlier at Ondwe, Magwe district, Upper Burma. Salt Deposits of Rajputana. Miscellaneous Notes.

Part 3.—Geology of Sarawan, Jhalawan, Mekran and the State of Las Bela. Hippurite-bearing Limestone in Seistan and Geology of adjoining region. Fusulinidæ from Afghanistan. Miscellaneous Notes.

Part 4.—Geology and Prospects of Oil in Western Prome and Kama, Lower Burma (including Namayan, Padaung, Taungbogyi and Ziaing). Recorrelation of Pegu system in Burma with notes on Horizon of Oil-bearing Strata (including Geology of Padaukpin, Banbyin and Aukmanein). Fossil Fish Teeth from Pegu system, Burma. Northern part of Yenangyat Oil-field. Iron Ores of Chanda, Central Provinces. Geology of Aden Hinterland. Petrological Notes on rocks near Aden. Upper Jurassic Fossils near Aden. Miscellaneous Notes. Index to Volume XXXVIII.

Vol. XXXIX, 1910.

Quinquennial Review of Mineral Production of India during 1904 to 1908 (*out of print*).

Vol. XL, 1910.

Part 1.—Pre-Carboniferous Life-Provinces. Lakes of Salt Range in the Punjab. Preliminary survey of certain Glaciers in Himalaya. D.—Notes on certain Glaciers in Sikkim. New Mammalian Genera and Species from Tertiaries of India.

Part 2 (out of print).—General Report for 1909. Mineral Production of India during 1909.

Part 3.—Revised Classification of Tertiary Freshwater Deposits of India. Revision of Silurian-Trias Sequence in Kashmir. Fenestella-bearing beds in Kashmir.

Part 4 (out of print).—Alum Shale and Alum Manufacture, Kalabagh, Mianwali district, Punjab. Coal-fields in North-Eastern Assam. Sedimentary Deposition of Oil. Miscellaneous Notes. Index to Volume XL.

Vol. XLI, 1911-12.

Part 1.—Age and continuation in Depth of Manganese-ores of Nagpur-Balaghat Area, Central Provinces. Manganese-ore deposits of Gangpur State, Bengal, and Distribution of Gondite Series in India. Baluchistan Earthquake of 21st October 1909. Identity of Ostrea Promensis, Noetling, from Pegu System of Burma and Ostrea Digitalina, Eichwald, from Miocene of Europe. Mr. T. R. Blyth. Miscellaneous Notes.

Part 2.—General Report for 1910. Devonian Fossils from Chitral, Persia, Afghanistan and Himalayas. Sections in Pir Panjal Range and Sind Valley, Kashmir.

Part 3.—Mineral Production of India during 1910. Samarskite and other minerals in Nellore District, Madras Presidency. Coal in Namchik Valley, Upper Assam. Miscellaneous Notes.

Part 4.—Pegu-Eocene Succession in Minbu District near Ngape. Geology of Henzada District, Burma. Geology of Lonar Lake, with note on Lonar Soda Deposit. International Geological Congress of Stockholm. Miscellaneous Notes. Index to Volume XLI.

Vol. XLII, 1912.

Part 1.—Survival of Miocene Oyster in Recent Seas. Silurian Fossils from Kashmir. Blödite from Salt Range. Gold-bearing Deposits of Mong Long, Hsipaw State, Northern Shan States, Burma. Steatite Deposits, Idar State. Miscellaneous Note.

Part 2.—General Report for 1911. Dicotyledonous Leaves from Coal Measures of Assam, Poting Glacier, Kumaon, Himalaya, June 1911. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1911. Kodurite Series.

Part 4.—Geological Reconnaissance through Dehong Valley, being Geological Results of Abor Expedition, 1911-12. Traverse across the Naga Hills of Assam. Indian Aerolites. Miscellaneous Notes.

Vol. XLIII, 1913.

Part 1 (out of print).—General Report for 1912. Garnet as a Geological Barometer. Wolframite in Tavoy District, Lower Burma. Miscellaneous Notes.

Part 2 (out of print).—Mineral Production of India during 1912. Relationship of the Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Hambergite from Kashmir.

Part 3.—Contributions to the geology of the Province of Yünnan in Western China: I.—Bhamo-Têng-Yüeh Area. II.—Petrology of Volcanic Rocks of Têng-Yüeh District. The Kirna Hills. Banswal Aerolite.

Part 4.—Gold-bearing Alluvium of Chindwin River and Tributaries. Correlation of Siwalik with Mammal Horizons of Europe. Contributions to the Geology of the Province of Yünnan in Western China: III.—Stratigraphy of Ordovician and Silurian Beds of Western Yünnan, with Provisional Palæontological Determinations. Notes on "Camarocrinus Asiaticus" from Burma.

Vol. XLIV, 1914.

Part 1 (out of print).—General Report for 1913. Carbonaceous Aerolite from Rajputana. Nummulites as Zone Fossils, with description of some Burmese species.

Part 2.—Contributions to the Geology of the Province of Yünnan in Western China: IV.—Country around Yünnan Fu. Dyke of white Trap from Pench Valley Coal-field, Chhindwara District, Central Provinces. Mineral concessions during 1913.

Part 3.—Coal-seams near Yaw River, Pakokku District, Upper Burma. The Monazite Sands of Travancore. Lower Cretaceous Fauna from Himalayan Gieumal Sandstone together with description of a few fossils from Chikkim series. Indarotos salmontanus Pilgrim. Future Beheading of Son and Rer Rivers by Hasdo.

Part 4.—Salt Deposits of Cis-Indus Salt Range. Teeth referable to Lower Siwalik Creodont genus 'Dissopsalis' Pilgrim. Glaciers of Dhauli and Lisar Valleys, Kumaon, Himalaya, September 1912. Miscellaneous Notes.

Vol. XLV, 1915.

Part 1.—New Siwalik Primates. Brachiopoda of Namyau Beds of Burma. Miscellaneous Note.

Part 2.—General Report for 1914. Note on Sivælurus and Paramachærodus.

Part 3.—Mineral Production of India during 1914. Three New Indian Meteorites. Kuttippuram, Shupiyan and Kamsagar. Dentition of Tragulid Genus (Dorcabune). Hematite Crystals of Corundiform Habit from Kajlidongri, Central India.

Part 4.—Geology of country near Ngahlaingdwin. Geology of Chitral, Gilgit and Pamirs.

Vol. XLVI, 1915.

Quinquennial Review of Mineral Production of India for 1909 to 1913 (*out of print*).

Vol. XLVII, 1916.

Part 1.—General Report for 1915. Eocene Mammals from Burma. Miscellaneous Notes.

Part 2.—The Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Iron Ore Deposits of Twinngé, Northern Shan States.

Part 3.—Obituary: R. C. Burton. Mineral Production of India during 1915. Flemingostrea, an eastern group of Upper Cretaceous and Eocene Ostreidæ, with descriptions of two new species.

Part 4.—Contributions to the Geology of the Province of Yünnan in Western China: 5.—Geology of parts of the Salween and Mekong Valleys. A fossil wood from Burma. The Visuni and Ekh Khera Aerolites.

Vol. XLVIII, 1917.

Part 1.—General Report for 1916. A revised classification of the Gondwana System.

Part 2.—Mineral Production of India during 1916. Mammal collections from Basal Beds of Siwaliks.

Part 3.—Crystallography and Nomenclature of Hollandite. Geology and Ore Deposits of Bawdwin Mines. Miscellaneous Notes.

Part 4.—Biana-Lalsot Hills in Eastern Rajputana. Origin of the Laterite of Seoni, Central Provinces.

Vol. XLIX, 1918-19.

Part 1.—General Report for 1917. Cassiterite Deposits of Tavoy. Les Echinides des "Bagh Beds.

Part 2.—Mineral Production of India during 1917. Support of Mountains of Central Asia.

Part 3.—Structure and Stratigraphy in North-West Punjab. Aquamarine Mines of Daso, Baltistan. Srimangal Earthquake of July 8th, 1918.

Part 4.—Possible Occurrence of Petroleum in Jammu Province: Preliminary Note on the Nar-Budhan Dome, of Kotli Tehsil in the Punch Valley. Submerged Forests at Bombay. Infra-Trappeans and Silicified Lava from Hyderabad, S. India.

Vol. L, 1919.

Part 1.—General Report for 1918. Potash Salts of Punjab Salt Range and Kohat. Origin and History of Rock-salt Deposits of Punjab and Kohat.

Part 2.—Tungsten and Tin in Burma. Inclination of Thrust-plane between Siwalik and Murree zone near Kotli, Jammu. Two New Fossil Localities in Garo Hills. Sanni Sulphur Mine. Miscellaneous Notes.

Part 3 (out of print).—Mineral Production of India during 1918. Gastropoda Fauna of Old Lake-beds in Upper Burma. Galena Deposits of North-Eastern Putao.

Part 4 (out of print).—Pitchblende, Monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. Natural Gas in Bituminous Salt from Kohat. Mineral Resources of Central Provinces. Miscellaneous Notes.

Vol. LI, 1920-21.

Part 1.—General Report for 1919. Pseudo-crystals of Graphite from Travancore. Mineral related to Xenotime from Manbhum District, Bihar and Orissa Province. Coal Seams of Foot-Hills of the Arakan Yoma, between Letpan Yaw in Pakokku and Ngapé in Minbu, Upper Burma. Observations on "Physa Prinsepii," Sowerby and on a Clionid Sponge that burrowed in its shell.

Part 2.—Classification of fossil Cypræidæ. Sulphur near the confluence of the Greater Zab with the Tigris, Mesopotamia. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1919. Results of a Revision of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma. Marine Fossils collected by Mr. Pinfold in the Garo Hills.

Part 4.—Illustrated comparative Diagnoses of Fossil Terebridæ from Burma. Indian Fossil Viviparæ. New fossil Unionid from the Intertrappean beds of Peninsular India. Unionidæ from the Miocene of Burma.

Vol. LII, 1921.

Quinquennial Review of Mineral Production of India for 1914-1918.

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Part 1.—General Report for 1920. Antimony deposit of Thabyu, Amherst district. Antimony deposits of Southern Shan States. Geology and Mineral Resources of Eastern Persia. Miscellaneous Notes.

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Part 3 (out of print).—Obituary: Frederick Richmond Mallet. Mineral Production of India during 1920. Mineral Resources of Bihar and Orissa.

Part 4.—Stratigraphy of the Singu-Yenangyat Area. Analysis of Singu Fauna. Sulphur Deposits of Southern Persia. A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica.

Vol. LIV, 1922.

Part 1.—General Report for 1921. Contributions to the Geology of the Province of Yünnan in Western China: VI.—Traverses between Tali Fu and Yunnan Fu. Geology of Takki Zam Valley, and Kaniguram-Makin Area, Waziristan. Geology of Thayetmyo and neighbourhood, including Padaukbin. Bitumen in Bombay Island.

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VOL. LV, 1923-24.

Part 1.—General Report for 1922. Indian Tertiary Gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ, Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species. Geological Interpretation of some Recent Geodetic Investigations (being a second Appendix to the Memoir on the structure of the Himalayas and of the Gangetic Plain as elucidated by Geodetic Observations in India).

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VOL. LVI, 1924-25.

Part 1.—General Report for 1923. Mineral Deposits of Burma.

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Part 1.—General Report for 1925. Foraminifera of parts of Western India.

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VOL. LX, 1927-28.

Part 1.—General Report for 1926. Six Recent Indian Aërolites.

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Vol. LXI, 1928-29.

Part 1.—General Report for 1927. Actionodon risinensis in Lower Gondwanas of Vihi district, Kashmir. Miscellaneous Note: Further Note on Nomenclature of Hollandite.

Part 2.—Contribution to Geology of Punjab Salt Range. Iron Ore Deposits of Northern Shan States. Lower Canine of Indian Species of Conohyus. Miscellaneous Note: Leucopyrite from Kodarma.

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Vol. LXII, 1929-30.

Part 1.—General Report for 1928. Miscellaneous Note: New Chromite Localities.

Part 2.—Obituary: Sivaram Sethu Rama Rau. Specific Gravity and Proximate Composition of Indian Vitrains. New Devonian Fossils from Burma. Rangoon Earthquakes of September and December 1927. Epicentre of North-West Himalayan Earthquake of 1st February 1929. Miscellaneous Notes: Indian Beryl, Atacamite in Bihar and Pyromorphite in Bhagalpur district, Bihar.

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Vol. LXIII, 1930.

Part 1.—General Report for 1929. Upper Triassic Fossils from Burmo-Siamese Frontier.—Thaungyin Trias and Description of Corals. Upper Triassic Fossils from Burmo-Siamese Frontier. Brachiopoda and Lamellibranchia from Thaungyin River. Upper Triassic Fossils from Burmo-Siamese Frontier.—Fossils from Kamawkala Limestone. Upper Triassic Fossils from Burmo-Siamese Frontier.—New Dasycladacea, *Holosporella siamensis* nov. gen., nov. sp., with Description of Allied Genus *Aciculella* Pia. Cretaceous Cephalopods in 'Red Beds' of Kalaw, Southern Shan States, Burma.

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Part 4.—Reaction Minerals in Garnet-Cordierite-Gneiss from Mogok. Vindhyans of western Rajputana. Granitic Intrusions in Ranchi and Singhbhum Districts. Miscellaneous Notes: *Chonetes* in Krol Limestone; Green Mica from Bhandara District; and Olivine-Basalt and Tuffs in Malani Series at Jodhpur.

Vol. LXVI, 1932-33.

Part 1.—General Report for 1931. Rudistæ from Eastern Persia.

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Vol. LXVIII, 1934-35.

Part 1.—General Report for 1933. Obituary: Malhari Vinayak Rao, Khanpur Meteoric Shower. Cambrian Sequence of Punjab Salt Range.

Part 2.—Cambrian-Trias Sequence of North Western Kashmir (Parts of Muzaffarabad and Baramula Districts). Preliminary account of Earthquake of 15th January, 1934, in Bihar and Nepal. Obituary: Pramatha Nath Bose. Miscellaneous Notes: Barytes in Manbhum District, Bihar; Soda Deposit and Manufacture of Caustic Soda and Crude Soap at Parantij, Ahmedabad District; Potash content of *Reshta*, Sambhar Salt Lake, Rajputana; Alunogen from Cuddapah District; and Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1934.

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Vol. LXIX, 1935-36.

Part 1.—General Report for 1934. Primitive Fossils, possibly Atrematous and Neotrematous Brachiopoda, from the Vindhyans of India. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1934, and Additional Note on Nomenclature of Hollandite.

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VOL. LXX, 1936.

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Part 2.—Perpeti Meteoric Shower of 14th May, 1935. Tirupati and Bahjoi Meteorites. *Ostrea (Crassostrea) gajensis* from near Baripada, Mayurbhanj State. *Matonidium* and *Weichselia* in India. Cretaceous Cephalopods from Red Beds of Kalaw and Age of Red Beds. Contributions to the Geology of the Province of Yünnan in Western China: 9.—Brachiopod Beds of Liu-wun and related formations in Shan States and Indo-China. Geological Age of Namyau, Liu-wun and Napeng Beds and of certain other formations in Indo-China. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1936.

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Page 155 : line 15 should *read*—belong to the space-group 0_h^{10} or Ia3d which is the space-group

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2] 1938 [December

THE GEOLOGY OF GUJARAT AND SOUTHERN RAJPUTANA.

BY B. C. GUPTA AND P. N. MUKERJEE, B.Sc. (CAL.), M.Sc. (LOND.), D.I.C., *Asstt. Geologists, Geological Survey of India.* (With Plates 1 to 5.)

CONTENTS

INTRODUCTION.

The area with which the following pages are concerned includes in its northern portion the southernmost States of the Rajputana Agency, namely, Dungarpur, Banswara and Kushalgarh in their entirety and Partabgarh in part. Extending southward the area covers the eastern tracts of the Mahikantha and Sabarkantha States and Lunavada, Sunth, Sanjeli, Kadana and Balasinor States of the Rewakantha States Agency. Farther south, stretching across the Panch Mahals district and the eastern fringes of Ahmedabad and Kaira districts of the Bombay Presidency, the area includes the Rewakantha States of Bariya and Chhota Udepur. Part of the eastern margin of Baroda State, together with numerous small feudatory States of the Rewakantha States Agency lying north of the Narbada river, forms the southern limit of the area. The western border of the area under

Area.

review is fringed by the fertile alluvial plains of Gujarat, while the western margin of the great Malwa plateau flanks it on the east.

The area is nearly 13,000 square miles in extent and lies between the parallels of 22° and 24° north latitude, and 73° and 74° 45′ east longitude.

The geological account of the area which is presented herein is based mainly on two distinct periods of field-work with a hiatus of nearly twenty years between them.

Field-work.

The first was that of by the Central India and Rajputana party during the years 1907 to 1914 under the superintendence of Mr. C. S. Middlemiss: the late Mr. N. D. Daru was chiefly responsible for the survey of the Southern Rajputana States of Dungarpur and Banswara, and the adjoining Rewakantha States of Sunth and Kadana, while Mr. H. Walker and Dr. A. M. Heron in 1907 and 1908 geologically surveyed the Central Indian State of Jhabua, and Partabgarh and Kushalgarh, the western fringes of which comprise the eastern margin of the area under review.

The second period of field-work, extending over the successive field-seasons between 1931 and 1935, was undertaken by the authors as members of the Rajputana and Bombay party, under the guidance of Dr. A. M. Heron, with a view to extend the previous work of the Central India and Rajputana party southward into the Bombay Presidency.

The intervening period between these two series of field-work has been productive of far-reaching results regarding the succession and correlation of the Archæan formations of Rajputana and its neighbourhood. The authors thus had the advantage of a definite lead in the execution of their own work as well as in the interpretation of the work of their predecessors in the area.

Links with surrounding areas.

Essentially the area is the southern continuation of the ancient metamorphic regions of Rajputana. The north-western portion of the area represents the south-western extremity of the Aravalli range,—much broken and ultimately lost in the low-lying alluvial tracts of Gujarat.

Mr. C. S. Middlemiss, in the course of his geological survey of Idar State, surveyed this portion of the area in great detail. His scale of formations, as far as the metamorphic rocks are concerned,

has been reversed as a result of subsequent work establishing connection between his survey and that of Dr. Heron in Rajputana.[1] The Phyllite Series of Middlemiss has been found to correspond with the Aravalli phyllites, and his Delhi Quartzite Series is partly the Delhi basement series, the Alwar quartzites, and partly quartzites intercalated in the Aravalli system. Thus interpreted, and greatly generalised, the eastern portion of Middlemiss' geological map of Idar State has been incorporated in the map accompanying this paper.

At its south-western corner the map includes the eastern fringe of R. Bruce Foote's geological map of Baroda[2], showing an extensive alluvial area diversified at its north-eastern margin by much worn down heaps of dark Deccan trap.

In the south the map just overlaps the north-western margins of the maps representing the work done by W. T. Blanford in the Taptee and Narbada valleys[3] and P. N. Bose in the lower Narbada valley.[4] The ancient metamorphics are mostly represented by gneissic rocks along this border, except where these are covered by extensive lava piles, the northern continuation of the Deccan trap flows of Rajpipla, mapped and described by P. N. Bose.[5]

Uninterrupted sheets of extensive lava flows join up the eastern margin of the area with the Malwa plateau, geologically surveyed by H. Walker and A. M. Heron.

Patches of infra-trappeans, often intervening between the ancient metamorphics and the extensive lava flows, have been recorded at several localities in the area under review. These have been correlated with the Bagh beds,[6] the Lameta series[7] and the Nimar sandstones[8] in consideration of their lithological characters and fossil contents.

Previous observers.

In the early sixties of the last century W. T. Blanford and A. B. Wynne, in the course of their work in western India, geologically surveyed portions of the southern fringe of the area under review.[9]

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 107, (1931), 72, p. (1938).
[2] 'The Geology of Baroda State', by R. Bruce Foote, 1898.
[3] *Mem. Geol. Surv. Ind.*, VI, pt. 3, (1869).
[4] *Op. cit.*, XXI, pt. 1, (1884).
[5] *Rec. Geol. Surv. Ind.*, XXXVII, pt. 2, (1908-1909).
[6] W. T. Blanford, *Mem. Geol. Surv. Ind.*, VI, pt. 3, p. 207, (1869).
[7] J. G. Medlicott, *Op. cit.*, II, p. 196 (1860).
[8] P. N. Bose, *Op. cit.*, XXI, pt. 1, pp. 3, 23, (1884).
[9] *Op. cit.*, VI, pt. 3, (1869); *Rec. Geol. Surv. Ind.*, V, pt. 3, (1872).

R. Bruce Foote visited the south-western corner of the area in the course of his geological survey of Baroda State, under the auspices of the Baroda Durbar, during 1891 and 1894.[1]

Sir L. L. Fermor investigated the geology of a portion of the southern tracts of the Panch Mahals district in 1905 in connection with his investigation of the manganese deposits of India.[2] His detailed study of the lavas of the Pavagad Hill provides a supplement[3] to Blanford's pioneer work[4] on them.

The north-western corner of the area, composed of the eastern portion of Idar State, was surveyed by C. S. Middlemiss during 1911 and 1916.[5]

Results of a geological traverse between Pavagad (22° 28′ : 73° 31′) and Dohad (22° 50′ : 74° 15′) of the Panch Mahals district, have been recorded by E. J. Beer in the Transactions of the Mining and Geological Institute of India.[6]

The north-western tracts of Chhota Udepur State, near the southern end of the area under review, were geologically surveyed by G. V. Hobson during 1923-1924, and described in his paper on "The metamorphic rocks and intrusive granite of Chhota Udepur State".[7]

Bariya State, adjoining Chhota Udepur on the north, was geologically surveyed by B. Rama Rao during 1930-1931. A report of his work has been published by the Bariya Durbar.[8]

Dr. P. K. Ghosh, when working in southern Mewar, made a special study of a group of much metamorphosed ultrabasic intrusives occurring in the neighbourhood of Kherwara (23° 59′ : 73° 36′). These rocks extend southward across the State boundary into Dungarpur State. The results of Dr. Ghosh's investigations, along with a geological map showing the distribution of these rocks in southern Mewar and Dungarpur, have been published in his paper on the "Talc-serpentine-chlorite rocks of southern Mewar and Dungarpur".[9]

[1] Geology of Baroda State, R. B. Foote, (1898).
[2] *Mem. Geol. Surv. Ind.*, XXXVII, pt. 2, pp. 281-282, (1909).
[3] *Rec. Geol. Surv. Ind.*, XXXIV, pt. 3, pp. 148-166, (1906).
[4] *Mem. Geol. Surv. Ind.*, VI, pt. 3, pp. 343, 344, (1869).
[5] *Op. cit.*, XLIV, pt. 1, (1921).
[6] *Trans. Min. Geol. Inst. Ind.*, XIII, (1918).
[7] *Rec. Geol. Surv. Ind.*, LIX, pt. 3, pp. 340-357, (1926).
[8] Geology of Bariya State (Rewakantha), (1931).
[9] *Rec. Geol. Surv. Ind.*, LXVI, pt. 4, pp. 449-460, (1933).

PHYSICAL FEATURES.

Topography.

Topographically the area consists of three well-marked divisions. Of these the elevated undulating plains, occupied by the metamorphic rocks, cover by far the greater part of the area. The other two divisions are the low-lying alluvial plains of Gujarat on the west and the western edge of the Malwa plateau, rising to an elevation of about 1,500-1,700 feet above sea level, on the east.

Metamorphic area.

The topographical aspects of this portion of the area vary widely from place to place. The extensive metamorphic region is essentially a much eroded peneplane and presents a diversified countryside consisting of rocky hills, long, straight or sinuous ridges alternating with narrow valleys or flat alluvial plains.

The topographical variations are directly referable to the lithological differences in the constituent rocks of the areas concerned.

The phyllites and schists generally form soft and crumbling outcrops giving rise to rolling hummocky topography. The valleys and plains are mainly occupied by such softer rocks, prone to be buried under the soil derived from their own disintegration. The extensive lands sketchily cultivated by the Bhils, and often dotted with low hills or discontinuous ridges, furnish the best illustrations.

The quartzites associated with the phyllites and schists, from their superior hardness, withstand weathering better and thus in places form steep, narrow ridges, often with characteristically serrated tops, arranged along the strike.

Remarkable instances of such ridges are seen in great abundance in the central tracts of Bariya State, where the chains are symmetrically sinuous in their extension, showing a remarkable parallelism in their strike.

Farther to the north and north-west, in Sunth, Sanjeli, Lunavada and Kadana States, innumerable chains of steep continuous ridges, often running in parallel and sinuous strikes, alternating with narrow, low-lying, well-watered valleys, have imparted a picturesque variety of scene to the central hilly region of the area.

Along the north-western frontier of Lunavada State, where it abuts against Balasinor and Mahikantha States, the country abounds

with straight, parallel ridges, with a general north-east and south-west strike. These vary considerably in length from mere ridgelets not more than a mile in length to chains extending over fifteen to twenty miles. Their width is also variable from place to place along the strike. Although seldom rising more than 300 feet above the ground level, these ridges, in their steep and straight attitude in the midst of the surrounding flat or hummocky country, form very striking features of the local landscape.

The Southern Rajputana States of Dungarpur and Banswara, forming the northern portion of the metamorphic area, show characteristically uneven topography, owing to an irregular assemblage of numerous hills and ridges not generally attaining any great relative height.

But for a rocky belt along the northern frontiers of the States of Chhota Udepur and Alirajpur, the metamorphic area in the south has generally a more even topography, being less frequently interrupted by relict ridges of harder rocks.

Stretching north-west and south-east across the Godhra *taluka* of the Panch Mahals district an extensive tract of a typical granite country borders the metamorphic area on the west for a length of nearly fifty miles. It has an average width of about ten miles. The area is characterised by a general flatness, the monotony of which is broken by occasional mounds and detached ridges rising from the undulating plain, often to an altitude varying from 450 to 550 feet above the general level of the country.

Several steep-sided and almost flat-topped elevated tracts form distinctive features of the landscape in certain parts of the Panch Mahals district and its neighbourhood. The margins of these miniature plateaux have a general north and south trend, but in detail they are extremely irregular. These highly indented tablelands evidently represent outlying portions of the Malwa plateau, the western edge of which is only a few miles to the east.

Malwa plateau.

A strip of the western border of this historic plateau is included in the area under review. It is an elevated tract varying from 1,500 feet to 1,700 feet in altitude, but appearing to the eye to be of almost perfect flatness, except where low trap hills rise from the uniformity of black cotton soil, derived from the dark Deccan trap lava, the solid rock of the plateau.

At its western edge the plateau drops sharply and gives place to a wilderness of steep, stony ridges and hills. The plateau is highly indented along this entire length. Long, narrow tongues of land stretch out from the main mass and detached conical or table-topped hills, often rising as high as the plateau itself, fringe the margin.

The normal level of the unconformity between the metamorphic rocks and the overlying trap is about 900 feet; the metamorphics pave long inlets along the bottoms of the valleys in the margin of the Malwa plateau wherever the erosion has gone deep enough to reach the level of the unconformity.

Alluvial plain.

The western flank of the area under review shows a more or less continuous alluvial belt extending southward from Idar State across the eastern tracts of the Ahmedabad and Kaira districts to the north-eastern regions of the Gaekwar of Baroda's territories. But for a few conspicuous outcrops of the Deccan trap and the ancient metamorphic rocks rising like hilly islands through the alluvial belt near its eastern margin, the country appears to be a dead flat. The eastern margin of the alluvial belt is marked by a series of embayments of alluvial tracts alternating with peninsula-like protrusions of the metamorphic area. Evidently this represents the eastern frontier of the coastal band of alluvium formed by the detrital deposits brought down by the rivers of southern Rajputana, Gujarat and the western slopes of the Malwa plateau.

Drainage.

The entire body of the effluent surface water of the area finds its way ultimately into the Arabian Sea through three distinct river systems, namely the Sabarmati, the Mahi and the Narbada.

Mahi system.

The mighty Mahi, with its innumerable tributary streams draining the western margin of the Malwa plateau as well as the metamorphic and the alluvial tracts, is *par excellence* the river of the area. Rising in the Malwa plateau, the river follows a general north-north-westerly course till it reaches the metamorphic tracts at the southern frontier of Banswara State in southern Rajputana. From there it flows northwards up to the northern limit of the State and then turning west-

ward forms, for a few miles of its course, the natural boundary between Banswara and Mewar. Here the Mahi is joined by the united streams of the Som and the Jakham, two important rivers of southern Mewar. Hereafter the Mahi follows a general south-westerly course diagonally across the area and finally flows into the Gulf of Cambay.

Of the other tributary streams of the Mahi, the Anas and the Panam are the most important. Both these streams have their sources near the south-eastern corner of the area under review. With an average height of about 1,200 feet above sea-level, this tract forms a small local watershed. On its north the country slopes northwards and the area is drained by many tributary streams of the Anas. The Anas continues its northerly course through the western tracts of Jhabua State and finally falls into the Mahi after attracting the entire drainage of the eastern *talukas* of the Panch Mahals district and the southern tracts of the Banswara State. On the west of the highland the Panam starts on its west-north-westerly course and rapidly gains in volume and importance by absorbing the streams of the northern frontier of Alirajpur, and of the southern tracts of Bariya. West of Devgad-Bariya (22° 42′ : 73° 53′) the Panam takes a definite northerly turn and ultimately flows into the Mahi near Lunavada (23° 8′ : 73° 37′). The country west of this section of the Panam slopes steadily towards the west. The western *talukas* of the Panch Mahals district are thus drained by another series of tributary streams of the Mahi having a general westerly course. The Kun, the Mesri, the Goma and the Kerad are the most notable members of this series.

Sabarmati system.

The north-eastern tracts of the area are drained by several important tributaries of the Sabarmati river, which flows through Idar State just beyond the western boundary of the area under review. Of these tributaries the Hathmati, the Meshwa, the Majham and the Vatrak are the most noteworthy. Flowing south-westerly along strike valleys they have more or less parallel courses within this area.

Narbada system.

The southern portion of the area is drained by the tributaries of the Narbada, which runs its westerly course just outside the southern boundary of the area. A belt of rocky country, beginning from the south-western extremity of the Bariya State and stretching east and west across the entire width of the metamorphic area, forms the water-

parting between the Mahi and the Narbada systems of drainage. The entire body of effluent water of the southern Rewakantha States finds its way to the Narbada through its important northern tributaries, the Orsang, the Aswan and the Men.

Climate.

A considerable diversity of climatic conditions is experienced in different parts of the area.

The elevated margin of the Malwa plateau is fairly cool except from the beginning of April to the setting in of the rainy season in June. During these months the area is swept by persistent, dry, hot, west winds. The rainfall is moderate, being 30 to 40 inches annually. The cool season lasts about four months, from the beginning of November to the beginning of March. The atmosphere during this period is clear and dry and the climate is healthy.

The northern tracts of the area under review, consisting of the Mahikantha States and the Southern Rajputana States, enjoy a fairly healthy climate. The division of the year into a hot season, a rainy season and a cold season holds equally good in this part as on the plateau margin. The first and the last, however, are more contrasted, and the annual rainfall is heavier in this area.

The central belt of the area is subject to considerable variations of temperature. Periods of severe cold occur between the months of December and January, frosts often damaging the crops and at times ice forming on shallow pools. During the summer months, again, the heat is often very intense. The average rainfall is about 30 inches. The rainy season is hot and close. The climate is not healthy within this belt. Some of the forest-covered tracts of the Eastern Rewakantha States are unhealthy during the post-monsoon period of the year.

The climate of the southern belt is decidedly moist in comparison with that obtaining in the north. The average rainfall is about 50 inches. Dense teak and *mahua* forests with wild creepers and grassy undergrowth often cover much of the hilly tracts. These prevent free and speedy evaporation of water and keep the atmosphere moist and unwholesome. The cold in January in these parts is very severe, and the heat in May equally so.

Vegetation.

The area is marked by great diversity of vegetation. The highlands of the Malwa plateau margin are generally poorly provided with big trees. The fertile black cotton soil with which the plateau is covered bears magnificent crops, and the country is extensively cultivated. Of the great variety of crops raised the most important are: opium-poppies, wheat, cotton, maize, juar, gram and various oilseeds.

At its western edge, where the plateau drops sharply, the country is extremely rocky and devoid of soil or water, except in the broader valleys, where the Bhils attempt some rude cultivation and their usual food crops are raised.

The eastern tracts of the Mahikantha States Agency and the Southern Rajputana States of Banswara and Dungarpur, forming the northern portion of the area, are generally rough and wild. The vegetation is poor and generally scrubby. The *mahua*, the mango and the *nim* are often seen near villages. The chief crops grown are wheat, rice, bajra, gram, cotton, sugarcane and oilseeds.

But for a few reserved tracts in Bariya State the central belt of the area as a whole is fairly open and poorly wooded. The bigger trees stand singly or in small local groves. Chief amongst these are, mango, *mahua*, *nim*, tamarind, *bor*, banyan and *pipal*. Wild date and palmyra palms also occur. The area is characterised by extensive agricultural lands. The chief crops are wheat, juar, bajra, maize, cotton, gram and oilseeds. Chillies and turmeric are also grown.

The greater part of the southern country, consisting of the southern members of the Rewakantha States, is covered with forests, of which the most valuable are in Bariya State. The commonest tree is the *mahua*, found most abundantly in Bariya and Chhota Udepur. Teak is also abundant, but generally stunted. Tamarind and mango are also very common near the village areas.

GEOLOGICAL FORMATIONS.

A highly intricate and varied gneissic complex represents the oldest formation of the area. This is continuous with the pre-Aravalli gneissic complex of central Mewar.[1]

[1] *Mem. Geol. Surv. Ind.*, LXV, pt. 2, pp. 116-140, (1934).
Trans. Nat. Inst. Sci. Ind., 1, no. 2, pp. 21-23, (1935).

Lying unconformably on this basement gneiss is a metamorphic series consisting of a recrystallised arenaceous and impure calcareous facies along with an extensive development of slaty, phyllitic and micaceous schistose formations. These have a general northerly strike and are continuous with the Aravalli formations mapped farther north in Rajputana.

Quartzites representing the south-western continuation of the Alwar series of the Delhi system of Rajputana have been mapped in the north-western corner of the area.

Acid igneous rocks, intrusive into the Aravalli and the Delhi formations, are widely distributed in the area.

There is a vast hiatus in the chronological sequence subsequent to the development of the Delhi system and the associated igneous rocks in the area. The entire Palæozoic group is absent. The uppermost system of the Mesozoic group is represented by several patchy outcrops of fluviatile and estuarine deposits, the infratrappean formations of the area. These are either calcareous or arenaceous and show no alteration.

Overlying these and often resting directly on the ancient metamorphics are a series of lava flows, mostly basic in composition,—the Deccan traps.

No tertiary formations have been seen in the area under review. The Archæans as well as the younger rocks have been irregularly overlaid by post-tertiary deposits of recent and sub-recent soils, *kankar*, etc.

Table of formations present.

Recent and Post-Tertiary.	Recent and sub-recent soil. Kankar, calcareous conglomerate, laterite, *etc.*		
			Erosion unconformity
Eocene . .	Deccan trap.		
			Eruptive unconformity
Cretaceous .	Infratrappeans.	Bagh beds, Lameta beds, Nimar sandstone. Ahmednagar sandstone.	
			Erosion unconformity

Algonkian .	Delhi system. Alwar quartzites.		
			Erosion
			unconformity
Archæan .	Aravalli system	Composite gneisses, phyllites, slates, and schists with quartzitic intercalations.	Intrusive quartz veins, pegmatites, granite. Epidiorites (amphibolites).
		Limestone.	
		Basal quartzite and conglomerate.	
			Erosion
			unconformity.
	Pre-Aravallis .	. Banded gneissic complex.	

BANDED GNEISSIC COMPLEX.

Near the north-eastern corner of the area, portions of the southern Rajputana States of Partabgarh, Dungarpur and Banswara are occupied by a highly intricate and varied gneissic complex. It is throughout a region of extreme metamorphism and rapid alternation of heterogenous assemblages of rock types, mostly igneous in origin. Very often, on account of intimate intermixture or interfoliar injection, these have entirely lost their distinctive original characters.

Streaky composite gneisses with widely varying texture and composition, associated with granite, aplite, pegmatite and amphibolite, are the chief members of the intrusive complex. Separate mapping of these has not been attempted on account of their intimate association and intermixture. The gneisses have a general northerly foliation strike, and are continuous with the pre-Aravalli banded gneissic complex of Central Mewar [1].

As regards the relative ages of the different members of the gneissic complex, observations in the area under review have been confirmatory to the views expressed on the subject in the memoir on the 'Geology of Central Mewar' [2].

[1] *Mem. Geol. Surv. Ind.*, LXV, pt. 2, pp. 116-140, (1934). *Trans. Nat. Inst. Sci. Ind.*, I, no. 2, pp. 21-23, (1935).
[2] *Mem. Geol. Surv. Ind.*, LXV, pt. 2, p. 126.

Gneisses and Granites.

As a rule, the granites and gneisses are intimately associated with one another and are notable for their acid character. Typical exposures show broad bands and lenticles of coarse or fine-grained granite alternating with banded gneisses, pegmatites and aplites, the whole often injected copiously in every direction with quartz veins and occasional bands of basic intrusive rocks, forming a mass extremely heterogenous in appearance.

In Banswara and Partabgarh granitic texture is much more common than the gneissic. Extensive belts of true gneisses are absent, and massive, homogeneous granites prevail in the Mahi valley of the eastern tracts of Banswara State.

Near Khalda (23° 36′ : 74° 34′) the granite exposure shows a coarse, sometimes porphyritic rock, consisting of quartz, orthoclase, microcline, green biotite, sphene, ilmenite and apatite (21/661, 6708) and (21/674, 6719)[1]. Muscovite is occasionally seen (21/582, 6644) and hornblende is also sometimes present (21/643, 6693).

The gneissic forms prevail near Banswara town (23° 33′ : 74° 27′). Epidote is a very prominent secondary constituent in the gneiss of this locality. It occurs mainly along joints and as lenticular bands along the foliation. The mineral imparts a striking green and pink banded appearance to the rock (21/575, 6637).

Farther north, in the area between Kotwal (23° 59′ : 74° 32′) and Morwani (23° 46′ : 74° 34′) coarse, unfoliated granite is the predominant rock type. Of the constituent minerals felspar is generally weathered or saussuritised, there is often an intergrowth of quartz and felspar, microcline is occasionally present, and biotite, sometimes weathered into chlorite, is the commonest ferro-magnesian mineral. Magnetite and ilmenite are the usual accessory minerals.

In the rocky area between Sarodia (23° 55′ : 74° 28′) and Khajuri (23° 36′ : 74° 36′) the intrusive is characterised by the predominance of its felspathic constituent and corresponding subordination or total absence of quartz. The rock may be classed as syenite. The felspar is much weathered. The mafic mineral is invariably biotite with occasionally a little hornblende or chlorite. Among accessory minerals, besides occasional small amounts of quartz, magnetite and ilmenite are often present.

[1] Numbers such as 21/661 refer to the registered number of the rock specimen in the collections of the Geological Survey of India, and numbers such as 6708 refer to the registered number of the thin section in those collections.

Pegmatite and Aplite.

Veins and dykes of pegmatite and aplite are intimately associated with the gneissic and granitic members of the complex. These show considerable variation of texture and composition. The pegmatite is composed of varying amounts of quartz and felspar. More or less regular intergrowths between the quartz and the felspathic constituents of the pegmatite, resulting in the characteristic graphic texture often readily discernible in hand-specimens, have been noticed in several places. An almost continuous belt of graphic granite with an average width of three to four miles, running north and south along the east bank of the Mahi, has been found penetrating through the gneiss north of Bankawara (23° 38′ : 74° 8′).

Muscovite is occasionally present in the pegmatite as an accessory constituent. The pegmatite generally shows effects of intense shearing and torsion, often resulting in much crumpled foliated bands interfolded in the gneisses in which they are intrusive.

Besides pegmatite and aplite, veins of felspar have also been noticed at numerous places in the area covered by the gneissic complex. Generally these are much fractured and crushed.

A noteworthy instance of an autoclastic agglomerate composed of fairly large fragments of plagioclase felspar cemented by infiltrated silica, has been noted in the gneissic rocks south of the peak 1190 (23° 43′ : 74° 25′).

The northern margin of the syenitic belt, south of Sarodia (23° 55′ : 74° 28′) is marked by satellitic dykes and veins of felspar porphyry. The rock exhibits much weathered and saussuritised orthoclase phenocrysts along with specks of accessory biotite and ilmenite in a granular or crypto-crystalline matrix of quartz and felspar.

Occurrences of aplite containing quartz with orthoclase and plagioclase and also micrographic intergrowth of quartz and felspar have often been recorded in the gneissic complex. Epidote, chlorite and sphene are the common accessories of the aplitic intrusives.

Veins of quartz, generally much broken, are common in the gneissic area. These have not only accompanied all the acid intrusives but have also been found to be intrusive in the basic members of the complex.

Amphibolite.

Altered basic members of the intrusive complex, characterised by the presence of hornblende, sometimes replaced by chlorite, as the chief constituent, have been grouped together under the general term amphibolite. The range of variation in texture and composition of these basic rocks is, however, wide. Compact, massive dykes running parallel to the general foliation-strike of the gneisses are found in equal abundance with the foliated or highly schistose forms of the basic metamorphics occurring in close and often confusing intermixture with the gneiss. The foliated types weather comparatively easily and generally do not form any marked relief in topography. Their exposures are mostly to be found in stream-beds and river-sections of the area.

Metamorphosed basic dykes are frequent in the gneissic complex of the Partabgarh-Banswara frontier area. These almost invariably run parallel to the foliation-strike of the gneiss and are discontinuous. The longest ones could only be traced to a distance of about two miles. The dykes vary considerably in width, but nowhere exceed a hundred feet. The dyke rock is hard and compact, and is traversed by pronounced joints.

The dykes diminish in thickness and number when followed southward, and are often replaced by hornblende-schists. These are either coarsely crystalline or finely granular.

North-east of Pipalkunt (23° 48′ : 74° 34′) the dyke rock has been found to have intruded into the gneiss; while three miles east of Kotwal (43° 59′ : 74° 32′) it is intrusive in the granite of the area.

Under the microscope the dyke rock shows mainly brown, pleochroic hornblende with subordinate amounts of granular quartz and plagioclase felspar. Epidote is occasionally developed along cracks and joint-planes.

Relation of the Gneissic Complex to the Aravallis.

The junction between the gneissic complex and the Aravallis in Mewar has been found to be marked by frequent bands of conglomeratic or gritty quartzitic formations, the latter often showing evidence of 'false-bedding'. These led to the conclusion that the junction between these two formations is one of erosion unconformity, the gneissic formation representing the basement rock,

upon the weathered and eroded surface of which the basal members of the Aravalli system were deposited[1].

Further occurrences of conglomeratic formations, often containing pebbles apparently derived from the members of the gneissic complex, have been recorded in several places along the junction of the two formations in the area under review. These confirm the conclusion regarding the correlation already arrived at while working on the northern extension of these formations.

ARAVALLI SYSTEM.

Distribution.

The Aravallis form by far the most wide-spread geological unit in the southern Rajputana and the northern Rewa Kantha States.

The system is represented by (1) a basal quartzitic formation, often conglomeratic, (2) an impure calcareous facies, generally dolomitic in composition and (3) an argillaceous series consisting of slaty, phyllitic and micaceous types along with arenaceous intercalatory bands.

It has not been possible to map the various types of the argillaceous metamorphics separately. The intermittently soil-covered condition of the country and the infinite gradation obtaining between the different types have rendered any attempt at separate mapping of these on the one inch to the mile scale maps impracticable.

On the south the Aravalli schists are bounded by an extensive exposure of a streaky and highly foliated biotitic gneiss. The junction is much blended and the formation has all the appearance of a composite or mixed gneiss.

South of the gneissic belt the Aravallis are again seen extending over the southern tracts of the Panch Mahals district and the neighbouring States of the Rewa Kantha Agency.

Relation to the Champaners.

A portion of these southern exposures of the ancient sedimentary metamorphics has been described by W. T. Blanford under the local name of the Champaner series in his memoir "On the geology of the Taptee and Lower Narbadda valleys and some adjoining districts". He classed the Champaner beds with the 'Azoic group' of the area leaving 'the question of their geological horizon quite open' [2].

[1] *Mem. Geol. Surv. Ind.*, LXV, Pt. 2, p. 128, (1934).
[2] *Op. cit.*, VI, Pt. 3, p. 189, (1869).

L. L. Fermor examined the Champaners near Shivrajpur (22° 25′ : 73° 37′) and drew attention to the similarity between the Champaners and the Dharwars[1].

The northern continuation of Blanford's Champaner beds has been studied by B. Rama Rao in the Bariya State. He tentatively correlated these partly with the Raialo series of Rajputana and partly with the Upper Dharwars of Mysore, and placed them in the Purana group[2].

In view of the continuous extension of the Aravallis southward into the Panch Mahals district and adjoining States and the close similarity in lithology and association of the Champaners with these, it has been definitely concluded that the Champaners are the southern extension of the Aravalli system[3].

Both in the northern and the southern exposures of the Aravallis the argillaceous variants of the system form its prevailing representatives; outcrops of the basal quartzites and the limestone are very few in number and limited in extent.

General description and lithology. Basal conglomerate and quartzite.

Instances of conglomeratic quartzites have occasionally been seen in the midst of the Aravalli schists in Banswara and Jambughoda States. Generally the occurrences are small, narrow and lenticular in shape. The highly disturbed and altered condition of these patchy exposures renders their stratigraphical significance obscure. They may either be truncated anticlinal crests of the Aravallis or may simply represent local shallow-water deposition of the Aravalli sediments.

Several discontinuous outcrops of conglomeratic quartzites flanking the pre-Aravalli gneissic complex and dipping below the Aravalli phyllites and schists have been traced in the Southern Rajputana States.

The exposure stretching between Padaria (23° 22′ : 74° 18′) and Potla (23° 11′ : 74° 26′) in Kushalgarh, furnishes the most noteworthy instance. The band is exposed at intervals along the course of the Haran river. Its dip varies from 40° to 70° towards

[1] *Mem. Geol. Surv. Ind.*, XXXVII, pt. 2, pp. 281-282, (1909).
[2] Geology of Baria State, p. 6, (1931).
[3] *Rec. Geol. Surv. Ind.*, LXVIII, pp. 25-26, 72, (1934).

the south-west. In its northern portion the conglomerate consists of pebbles of black mica-schists and quartzite imbedded in a dark matrix, which has itself become scnistose. The rock, occasionally, has a gneissoid appearance due to the quartz pebbles having been compressed into 'augen'. The matrix is often quartzitic and the rock may be devoid of pebbles for considerable distances, then appearing as a banded or massive quartzite, dark grey or black in colour. Following it S. S. E. along the strike, pebbles of gneiss appear, often as large as a man's hand, the black schistose fragments disappearing until, when the trap overlies it, the formation appears to grade into a banded gneiss. The foliation-strike of the gneiss is the same as that of the conglomerate and the transition seems gradual. This rock may either be metamorphosed arkose or may represent the original rock from which the conglomerate was partly derived. From field evidences, it appears the truth lies halfway between these two probabilities. The metamorphic action which occurred subsequent to the deposition of the conglomerate would be sufficient to effect coalescence between the two rocks in contact, as they would be similar in mineral composition, and partial remelting and intermixture would inevitably take place.

A series of outliers of the basal quartzites have been recorded near the boundary between Mewar and Partabgarh States in the midst of the banded gneissic complex. The rock consists of pebbles of grey, pink or white quartz held in a chloritic or sericitic matrix. A proportion of the pebbles, for small distances, is fairly uniform in size, though over long distances the range of variation in size is remarkably wide. The larger pebbles are flattened and lenticular in shape, occasionally simulating an 'augen' structure on the weathered faces of the outcrops.

Limestone.

No extensive, continuous outcrop of the Aravalli limestone has been mapped in the area. Generally the exposures are small and discontinuous. The outcrops are invariably rugged, much broken up and consist entirely of dislocated craggy blocks and rough boulders, affording absolutely no clue to the stratigraphical position of the formation in relation to the schists amidst which it usually occurs. Instances, however, have been recorded where the limestone occurs in juxtaposition with the basal conglomerate and underlies the argillaceous schists.

The limestone is generally of indifferent purity, containing argillaceous or siliceous impurities in varying proportion. A general characteristic of the impure Aravalli limestone is the fact that it is impregnated with reticulated siliceous veins, stringers or ribs, which on the weathering of the rock stand out as prominent interlacing ridges. When fairly pure the rock is either pink or greyish white in colour and more or less dolomitic in composition.

The formation varies widely in texture from place to place. In southern Rajputana and adjoining tracts the limestone is generally thickly bedded and coarsely crystalline. In the south, at the northern frontier of the Jambughoda State, it is mostly massive, compact or finely crystalline. The formation is invariably traversed by well developed joints and the outcrops weather dark grey and form characteristically uneven, dissected, rocky plateaus.

An interesting instance of the Aravalli limestone, interspersed by intrusive granite, has been noticed in Jhabua State, about five miles north of Anas Station (B., B. and C. I. Ry.) close to the village Rambhapur (22° 55′ : 74° 29′) at the confluence of the Anas and the Pat rivers. The outcrops are much broken and generally covered with rough blocks and boulders. The rock is much intruded by granite, veins and stringers of which are seen in considerable abundance in the rock. The limestone is fine-grained, compact, highly siliceous and often varyingly ferruginous, the ferruginous mineral being limonite. On fresh fracture the rock shows a buff or grey interior. The weathered outcrops are dark brown. The rock is irregularly fractured and cracked. Traces of veinlets of secondary siliceous materials are seen in irregular ramifications standing out on weathered surfaces of the much fractured limestone. Often these preponderate over the calcareous contents, small pieces of which are then found held in the siliceous network. Sometimes the veinlets of the secondary silicates also show evidence of intense brecciation, and blocks, recemented with ferruginous cherty material, are seen in great force in the midst of these outcrops of the impure limestone.

Argillaceous rocks.

The argillaceous facies of the Aravallis is represented by slaty, phyllitic and micaceous schistose formations.

Being usually soft and closely cleaved, these easily crumble on weathering and often lie buried under soil mantles of varying thickness.

The rock types show considerable variability of physical characters and mineralogical composition. Micaceous schists with well pronounced foliation and often studded with small garnet crystals, closely laminated, corrugated phyllitic formations, grey slaty rocks of varying hardness and finely laminated, soft siliceous shales, all forms have been noticed from place to place. As the nature of the country does not allow one to trace these variations systematically it is hard to delineate them and determine the progress of the metamorphic processes with any degree of accuracy.

Slaty forms of the argillaceous metamorphics occur in close association with the phyllitic schists of the area. These are generally soft, and their cleavage or lamination is usually too close to render them of any use as building stones. Instances have, however, been recorded where slaty tiles and slabs yielding good roofing and flooring material are available amongst the argillaceous metamorphics. A number of diggings have been recorded near the village Therka (23° 5′ : 74° 12′) south-east of Jhalod town (23° 7′ : 74° 9′). The cleavage is less pronounced and the slate in this locality has developed a slabby character suitable for quarrying in tiles and slabs of varying sizes. The rock is distinctly siliceous and often faintly micaceous at the partings.

Slate.

Extensive quarries of slates have been developed about one and a half mile south of Jhalod town (23° 7′ : 74° 9′). The rock is well traversed by master joints and yields fair-sized slabs and tiles in abundance. The colour varies between grey and brown. Incipient siliceous growths are often seen on the parting planes of the slaty formation.

The phyllites are generally dark grey in colour; the rock varies in hardness and fissility. In its typical form the phyllitic formation is characterised by pronounced foliation and by its softness. Thin intercalatory quartzitic bands often stiffen the phyllites. Intrusive veins of white quartz also sometimes bring about the same effect. Generally, however, the phyllites crumble readily under the attack of weathering agencies and are very prone to lie buried under the debris derived from their own disintegration.

Phyllite.

The formation is best exposed in the extensive rocky tracts of southern Rajputana and the adjoining Rewa Kantha States of the north. The argillaceous metamorphics along the Jhabua-Panch

Mahals frontier have also been mostly represented by the phyllitic schists.

The colour of the schists varies between shades of grey and green. Reddish brown staining of the schists, due to decomposition of the ferruginous contents, has also been noticed. Development of sericite between the laminae of the phyllitic formation has on rare occasions given the rock a silvery white tinge. Occurrences of incipient garnets and of small crystals of pyrite have occasionally been noted in the phyllites of the Southern Rajputana and Kadana States. In most cases the rock is very soft and devoid of tenacity or sheen and splits easily, yielding laminae of inconstant thickness and undulating, smooth surface.

The strike of the schists is generally N. N. W. - S. S. E. and the dip is either vertical or steeply inclined towards W. S. W. Local variation in dip is, however, frequently met with, and often evidences of local distortion to a remarkable degree.

Instances of fairly slabby forms of the phyllites have been noticed in several places. The occurrence at Tandladara (22° 53′ : 74° 28′) in Jhabua State is noteworthy. Slabs of quite convenient size, often measuring six feet by four feet with a thickness of four to six inches, have been extracted in considerable quantity by superficial digging. Quarrying, however, is difficult and risky owing to the steepness of the prevailing dip, which varies between 70° and 80° to the W. S. W.

Highly siliceous types of phyllite are common in Lunavada and Kadana States. These are pale grey on fresh fracture and weather dark on exposure. On weathering the rock forms a characteristically uneven and hummocky topography.

Micaceous schists.

The argillaceous metamorphics classed under the general name of 'micaceous schists' show considerable variation of form in the area under review. They are, as a rule, highly foliated, the foliation planes being invariably marked by lamellar or flaky micaceous constituents set in a granular quartzose groundmass. The proportion of these siliceous and micaceous elements in the rock is remarkably variable. From finely laminated, readily cleavable typical mica-schist to fairly slabby siliceous types marked by parallel orientation of the disconnected flakes of mica in them, all forms have been noticed. The colour of these rocks varies with that of the predominating micaceous element in them. When highly sericitic the schists

appear dull white, but generally the colour varies within different shades of grey on account of the differing amounts of biotite usually present.

The schists are generally soft, easily denuded and lie mostly hidden under their own debris, except where exposed by stream sections or road cuttings. The outcrops are usually of a crumbling and decaying nature, yielding sandy masses, spotted and freckled with black or bronzy mica and brown ferruginous stains.

In the Southern Rajputana States instances have been noticed where the phyllitic or slaty formations have gradually passed through a kind of knotted schist into biotite-garnet-quartz-schist.

Near Dohad (22° 50′ : 74° 15′) in the Panch Mahals district the schist is fairly siliceous. Microscopic examination shows (44/138 ; 22082) a schistose arrangement of granular quartz and patches of biotite. Rounded crystals of garnet, showing minute quartz inclusions, are distributed irregularly in the rock. The garnet is often enclosed in a rim of magnetite. Dark blotches of iron ores, mostly decomposition products of biotite, are also noticed.

Farther to the south, at the Panch Mahals—Ali-Rajpur frontier, the rock grades into a micaceous quartz-schist in which small crystals of brown garnet are occasionally discernible in the hand specimen.

The schists are much intercalated with quartzite bands in almost all the Rewa Kantha States. The schists as a rule occupy the strike-valleys sheltered by long chains of quartzite ridges and are mostly buried under a soil mantle.

Generally the schists are highly micaceous, soft and crumbling. A specimen (46/518 ; 23607) from the Kotharia (22° 42′ : 74° 1′)—Bar (22° 46′ : 74° 1′) valley of the Bariya State shows under the microscope much bleached biotite passing into muscovite and sericite, quartz grains often rolled out along the foliation-strike of the micaceous constituents, and garnet in porphyroblastic crystals. The garnet crystals are much cracked. Concentration of brown, limonitic material is noticed around the garnet crystals, as well as filling the cracks in them. Microscopic rods of tourmaline have been observed in fair abundance. Magnetite is present in subordinate quantity.

The micaceous schists of the north-western Rewa Kantha States of Lunavada and Balasinor show well pronounced foliation and are often studded with incipient garnet crystals. The rock is usually

greyish in colour and shows a finely schistose disposition of the specks and spots of biotite, muscovite and sericite in a siliceous groundmass.

Besides the fissile and yielding schists, readily crumbling into glistening sandy dust, occurrences of fairly thick-bedded, slabby types have also been occasionally noticed. They often yield easily to quarrying along the bedding planes and are excavated for building purposes.

Typical instances of these slabby formations are seen in some force north of Chamaria (23° 4′ : 73° 36′) in Lunavada State. In view of the marked preponderance of the granular matrix and the parallel streaky orientation of the micaceous elements in it, these rocks may more properly be called gneisses than schists.

Similar gneissic slabby types have been met with in the central plains of Bariya State. A specimen from north of Pipodara (22° 43′ : 74° 3′) shows under the microscope (46/485 ; 23609) a granular quartzose groundmass, containing flakes of biotite arranged with their longer axes parallel. The biotite is sometimes bleached almost entirely into colourless mica. In close association with the biotite, and to all appearance owing its origin at least partly to the alteration of the biotite, is noticed some epidote and zoisite, along with calcite. A few small rods of tourmaline also occur. A laminated or thin-bedded but fairly compact type, intermediate in composition and physical characters between the soft, crumbling mica-schist and the hard, grey quartzite, is met with near Limkheda (22° 50′ : 74° 0′). Under the microscope the rock (46/489 ; 23612) shows patches of biotite and garnet crystals in a groundmass consisting of a mozaic of fine-grained quartz. The biotite is often partly bleached and shows pleochroic halos. Chlorite, due to the alteration of biotite, has been noticed in places. The garnet crystals are ragged in outline and contain innumerable quartz inclusions. Slender needles of tourmaline and muscovite, as well as occasional patches of magnetite, are seen in the groundmass.

Instances of compact, highly quartzose forms have occasionally been noticed in the midst of the soft micaceous schists. Exposures occurring about three miles east of Edalwara (22° 41′ : 74° 4′) furnish typical illustrations. The rock under the microscope (46/487, 23611) shows biotite, occasionally chloritised partly or entirely, in a granular groundmass of equidimensional quartz grains. Sericite

is seen in the cracks of the quartz grains. Black iron ore, magnetite, with well defined outlines, is present in some force. Small stumpy crystals of tourmaline and apatite are also present. The rock may be termed a biotite-sericite-quartz-schist.

Quartzite intercalations in the Aravalli schists.

Intercalated quartzite bands are very common in the Aravalli schists. On account of the superior resistance they offer to the denuding agencies, in contrast with the crumbling schistose formations which adjoin them, the outcrops of these quartzite intercalations often constitute parallel chains of steep strike ridges sheltering the low-lying valleys occupied by the schists.

The bands of the quartzitic formations vary widely in size and extent. From small intercalatory ribbons measuring not more than a few inches in thickness to massive belts measuring more than 2,000 feet across, from locally limited exposures too small to be recorded on the one inch to the mile scale field-map, to impressive chains more than twenty miles in length, all have been met with in the area.

When fresh the quartzite is subtranslucent with a bluish or pinkish grey tinge. The weathered rock is dull and opaque and of a grey or brown colour. Generally the quartzite is compact, thick-bedded and coarsely re-crystallised. Somewhat irregular block jointing is common in the rock. The outcrops are usually much broken and dislocated, affording but few opportunities for measuring the dip, which, wherever discernible, has been found to be in conformity with the foliation-dip of the schists in which the quartzites occur.

The joint-planes of the quartzites are often marked by veins of white quartz, occasionally containing irregular sheaves and booklets of white mica. Several instances of much fractured grey quartzite, with the cracks filled with white quartz of secondary origin, have been noticed. Often the veinlets develop into aggregates of small pyramidal crystals lining the cracks and crevices of the rock. The best examples of these much fractured quartzites, irregularly veined with secondary white quartz, are to be seen south of Metral (23° 4′ : 73° 49′) in the Panch Mahals district.

Mixed gneisses.

The 'composite gneisses', a much metamorphosed and highly injected facies of the Aravalli schists recorded in the southern area of Central Mewar,[1] gradually pass into more or less unmixed slaty, phyllitic or micaceous schists in the Southern Rajputana States of Dungarpur and Banswara. The granite and pegmatite intrusives, interfoliar injection of which in the schists is responsible for the formation of these mixed gneissic rocks, have been less and less permeative in the south. For some distance the intrusives appear as small dykes and veins till they altogether cease to be the constant associates of the argillaceous schists.

In the south, the Aravalli schists mapped near the south-eastern tracts of the area under review are bounded by an extensive exposure of a gneissic formation. Its junction with the schists is very much blended. No gritty nor conglomeratic formation has been seen anywhere at the junction, which has been closely followed for a length of about fifty miles. On the other hand, rich development of garnets has been frequently noticed in the phyllitic and micaceous Aravalli schists along their contract with the gneiss. The junction, in all probability, is one of eruptive unconformity.

The gneiss near the junction is generally characterised by very close and pronounced foliation. The rock is soft and crumbling. Outcrops are often covered with alluvial soil of varying thickness. Highly banded biotitic occurrences, suggesting interfoliar injection of granitic matter in schistose formations, have sometimes been met with in the midst of the gneisses. When broken along the foliation these have all the appearance of a schist, but across the foliation their gneissic character is evident. The pink felspathic constituents of these sometimes occur as 'augen' wrapped in foliaceous biotitic material. The occurrences about four miles north-west of Bhabhra (22° 32' : 74° 20') furnish noteworthy instances of these highly foliated biotitic gneisses.

The gneissic exposures generally strike north-west and south-east, with foliation dips either vertical or highly inclined towards the north-east.

Farther south in the southern Rewa Kantha States the gneiss has been traced into homogeneous granite, greyish pink in colour and medium-grained in texture. It is composed of pink or grey

[1] *Mem. Geol. Surv. Ind.*, LXV, Pt. 2, pp. 152-153, (1934).

felspars, greyish, granular, subtranslucent quartz and small specks of mica, both dark and white.

INTRUSIVES IN THE ARAVALLIS.

Discontinuous lenticles of dark amphibolite are often found in the gneissic formation near its junction with the Aravalli schists. These have well defined junctions with the highly foliated gneiss, and, occurring as dark massive or schistose bands in the foliated, crumbling biotite-gneiss, they have all the appearance of metamorphosed intrusive dykes.

Amphibolite.

Intrusive granite in the midst of the Aravalli schists and limestone has been recorded between Visalpur (22° 55′ : 74° 26′) and Rambhapur (22° 55′ : 74° 30′) on the northern bank of the Anas. The outcrops do not rise much above the general ground level, and weather into grey knolls and flat domes. The rock is hard and breaks unevenly under the hammer. In the hand specimen it shows greyish quartz and pink felspar. The ferro-magnesian mineral, biotite, is characteristically scanty. Under the microscope (22075) the quartz is seen in allotriomorphic granular texture, the plagioclase felspars, belonging to the soda end of the series, mostly oligoclase, have a tendency to form phenocrysts, and are more or less clouded. Calcite and zoisite, derived from the decomposition of the plagioclase felspars, are present in considerable proportion. Biotite, present in flakes and small patches, is partly chloritised.

Granite.

The granite is obviously intrusive in the Aravallis. Tongues and apophyses have been traced into the adjoining phyllites. In the main outcrop the granite is characteristically variable in texture. Both coarse- and fine-grained forms are seen. The rock is often distinctly foliated. The foliation-strike is invariably parallel to that of the country rock, generally north and south.

An extensive occurrence of intrusive granite has been mapped around Godhra (22° 47′ : 73° 37′), the headquarters of the Panch Mahals district. To the north the granite extends across the southern boundary of the Lunavada State well into its interior. In the east it covers a large area in the south-western tracts of the Bariya State. In the west the granite crosses the Mahi into the Balasinor State and is mostly represented by scattered groups of outcrops in the midst of the Recent alluvial deposits. South-

wards the outcrops of granite extend across the Kalol *taluka* of the Panch Mahals into the Bariya State.

The granite is clearly intrusive in the Aravalli schists. Although generally the junction is soil-covered, instances have been noticed in Lunavada and Bariya States where tongues of the granite are traceable into the adjoining schists, and aplite and pegmatite dykes, evidently representing the residual products of differentiation of the magma, have been seen to traverse the surrounding country-rock as well as the granite masses. Xenolithic occurrences of the schists and gneisses have also been noticed in the granite.

The rock is remarkably free from dynamic effects. Its mode of occurrence and association with the Aravallis are clearly indicative of the fact that it has at no stage been involved in the tectonic movements responsible for the folding of the ancient sedimentaries. It is therefore quite probable that the granite is post-Delhi in age, although there has been no contact with that series in the area under review. In fact, it appears to be the Erinpura granite[1]. In this connection it may be noted that the thick muscovite and tourmaline-bearing pegmatite dykes of this granite are remarkably similar to the post-Delhi pegmatites of north-eastern Rajputana.[2]

The granite is generally unfoliated, although occasional instances of incipient primary banding are not altogether absent. In texture the granite varies between medium- and coarse-grained types, with a marked tendency towards porphyritic forms. The colour varies between pink and grey, depending on the colour of the dominant felspathic constituent.

Pronounced block and mural jointing are usual in the outcrops. The progress of differential weathering along the joint-planes has often resulted in fantastic 'galleries' and 'arches' besides the usual smooth rounded blocks heaped in characteristic mounds and 'tors'.

In view of the close similarity of mineral composition and physical characters, as well as mode of occurrence and association, of this granite to the Erinpura granite, scattered exposures of which are met with not many miles away from the extreme north-western outcrops of the granite under description, the latter may safely be correlated with the Erinpura granite.

Aplite and pegmatite dykes and veins are in frequent association with the granite. The north-western margin of the granite is

[1] *Trans. Nat. Inst. Sci. Ind.*, Vol. I, No. 2, p. 32, (1935).
[2] *Mem. Geol. Surv. Ind.*, XLV, Pt. 1, p. 98, (1917).

particularly marked by extensive dykes of coarse-grained pegmatite often showing tabular blocks of white or cream-coloured felspars, white translucent quartz and books of stainless muscovite. Well developed crystals of black tourmaline have often been noticed in the pegmatite.

Aplite and pegmatite.

DELHI SYSTEM.

Highly re-crystallised, massive quartzites representing the Alwar basal series of the Delhi system appear in the north-western corner of the area. These are in strike continuity with the Alwar quartzites of Mewar and north-eastern Rajputana. The detailed description and lithology of these rocks have been given by Mr. C. S. Middlemiss in " The Geology of Idar State ".[1]

INFRATRAPPEANS.

The Palæozoic era, following the deposition and development of the Archæans and the Puranas, is entirely unrepresented in the area under description. Patchy formations, belonging to the upper systems of the Mesozoic group, overlie the ancient metamorphics with marked unconformity. The eroded surfaces of these, again, have been overrun by the lava flows of the Deccan trap.

The infratrappean formations are generally thin and lenticular. They form irregularly eroded horizontal shelves capping the ancient metamorphics and often crop out from below the Deccan trap. The infratrappeans are characterised by considerable heterogeneity of composition and variability of respective thickness of the component beds from place to place. Instances of considerable lateral variation in the lithological characters of the beds are also common, and it is indeed difficult to draw up an accurate succession of the series, which may reasonably claim general application in the extensive area under description.

In view of fundamental differences in origin and distinctive lithological characters, the infratrappeans of the area have been classified under (1) the Ahmednagar sandstone, (2) the Lameta beds, (3) the Bagh beds, and (4) the Nimar sandstone.

These names were originally introduced into Indian geology by different workers at different times in the course of their work in widely separated parts of the country. Although the last three

[1] *Mem. Geol. Surv. Ind.*, XLIV, Pt. 1, p. 74, (1921).

probably represent more or less contemporary series of sediments, these local names have still their use in descriptive geology.

The Ahmednagar sandstone may be correlated as Lower Cretaceous, the Bagh beds as Upper Cretaceous; the Lameta beds and the Nimar sandstone are here unfossiliferous, but may be regarded as equivalent to the Bagh beds.

The Ahmednagar sandstone.

The Ahmednagar (Himatnagar) sandstones were first described by Mr. C. S. Middlemiss in Idar State.[1] These are generally composed of thick beds of undisturbed, horizontal freestone intercalated with shales and conglomerates. Several outcrops have been mapped in the western tracts of the area. These vary in colour between white and different shades of pink, red and brown.

Fossil plants, of Lower Cretaceous age, have recently been discovered in the Ahmednagar sandstones by Dr. A. M. Heron and the second author,[2] the latter being responsible for the palæontological portion of this paper: Himmatnagar (Ahmednagar) (23° 36′: 73° 2′) is just beyond the western limit of the area under description.

Mr Middlemiss first drew attention to this locality, but he was able to obtain only unrecognisable plant remains. He correlated the Ahmednagar sandstone with the Umia stage of the Upper Gondwanas, formerly thought to be Upper Jurassic, but now regarded as Lower Cretaceous, as the Umia plant-bearing beds are interstratified with marine deposits homotaxial with the Wealden of Europe.[3]

Professor B. Sahni[4] has described the plant remains from Himatnagar (Ahmednagar) as *Matonidium indicum*, sp. nov. and *Weichselia reticulata*, two Wealden genera. There is therefore little doubt that the Ahmednagar sandstone is Lower Cretaceous.

The Lameta beds.

A conglomeratic formation with a siliceous or calcareous matrix forms the bottom band of the series. This grades into progressively

Lithology.

gritty, siliceous or calcareous types, with the result that the bulk of the upper formation

[1] *Mem. Geol. Surv. Ind.*, XLIV, Pt. 1, p. 137, (1921).
[2] *Rec. Geol. Surv. Ind.*, 71, Pt. 1, p. 28, (1936).
[3] *Op. cit.*, XLVIII, p. 32, (1917), *Proc. Asiat. Soc. Beng.* (New Series), XVII (iv), pp. clxvi, (1922).]
[4] *Rec. Geol. Surv. Ind.*, 71, Pt. 2, pp. 152-165, (1936).

presents either a massive, earthy limestone or a calcareous gritty sandstone, varying in colour between grey and brown. Irregular concretions of secondary silica and quartzitic pebbles, both rounded and angular, are often seen to characterise the component bands. Cherty and chalcedonic stringers and veinlets are also seen in considerable force in the upper stages of the series. Often the limestone is mottled with limonitic spots and blotches.

It has been suggested by Sir L. L. Fermor and Dr. C. S.Fox[1] that the secondary silica of these concretions and veins has been derived by solution from the overlying Deccan trap.

Indeterminate fossil fragments have been found in the Balasinor exposures, but not in any of the other Lametas here.

Numerous lenticular outcrops of the Lametas, generally forming narrow fringes along the base of the Deccan trap, have been recorded in the area. Of these the following occurrences are most noteworthy :—

Distribution.

(1) The Kushalgarh-Banswara frontier.
(2) The Sunth State frontier adjoining the Jhalod *taluka* of the Panch Mahals district.
(3) The Dohad *taluka*.
(4) The Bariya State.
(5) The Balasinor State.
(6) The Lunavada State.
(7) The Gabat State.

Kushalgarh-Banswara.

Typical Lameta beds overlying the Aravallis and forming an irregular horizontal shelf protruding from below the Deccan trap, have been mapped from Rœnia Naika (23° 14′ : 74° 18′) southwards to Dungra (23° 11′ : 74° 19′). The greatest thickness of the outcrops is about ten feet, the maximum width being about half a mile. The formation is chiefly impure, pale purple, massive limestone, slightly crystalline, and containing grains and pebbles of quartz as well as irregular concretions of pinkish chalcedony, which stand out on the weathered surface. The pebbles are dull white or colourless and translucent. Towards the south the chalcedony forms a band of about one foot in thickness on the top of the limestone.

In the neighbourhood of the Sunth-Sanjeli border and near Jhalod, patches of Lameta limestones unconformably overlie the

[1] *Rec. Geol. Surv. Ind.*, XLIII, Pt. 1, p. 33, (1913).

Sunth.

Aravallis. The outcrops form irregular horizontal shelves protruding from below the Deccan trap. The greatest thickness measures about 15 feet. The rock is usually a pale purple massive limestone, frequently with grains and small pebbles of white translucent quartz. Irregular concretions of secondary silica and quartzite pebbles are common. Cherty and chalcedonic stringers and veinlets also occur in the rock. The limestone is often mottled with limonitic spots and blotches (44/132). On microscopic examination (22084) the rock shows sub-angular grains of quartz held by granular calcite cement. The limestone is variable in composition and has a sharp contact with the underlying Aravallis. The lithology and mode of occurrence suggests sedimentary deposition in shallow inland basins.

Dohad.

About four miles north-west of Dohad (22° 50′ : 74° 15′) an exposure of Lameta beds forms an elongated tableland in the midst of the Aravalli schists and phyllites. Not rising more than a few feet above the general level of the surrounding country, the exposure stretches north and south for about ten miles, with a variable width which nowhere exceeds two or three miles. The outcrop is not overlain by the Deccan trap.

Bariya.

The largest of the patchy outcrops of the Lametas in Bariya State constitutes the rectangular table-land of Jhabu (22° 40′ : 74° 10′) covering an area of about four square miles and forming a thin horizontal capping on the steeply folded Aravalli schists.

The outcrop is composed of impure siliceous limestone, associated with conglomeratic and concretionary sandstone. The total thickness is nearly forty feet.

Balasinor.

The Lametas are exposed extensively along the western frontier of the Balasinor State. Near Balasinor town they occur as thin cappings over the granite. Farther to the north the Lametas rise abruptly above the ground level of the alluvial tracts. At the north-western corner of the State they overlie the Aravalli schists and phyllites unconformably.

The beds are varyingly siliceous and calcareous. The outcrops generally form irregularly shaped, flat-topped shelves. The maximum thickness observed is nearly thirty feet. Most of the outcrops show an impure, massive limestone, often with pebbly and

concretionary bands. Cherty or jasperoidal intercalations have also been noticed.

Indistinct fragments of fossil lamellibranch shells have been occasionally noticed in the siliceous limestone in many places (46/510). In the hand-specimen the fragments appear as white or horny specks. These give the weathered rock a rather rough and variegated appearance on the surface. The white fragmentary chips effervesce strongly in dilute cold hydrochloric acid. Under the microscope (23615) they show rounded or subangular grains of quartz embedded in a ramifying calcareous groundmass often tinged with limonite. Minute flakes of biotite, partly chloritised, have also been noticed in the slide.

Lunavada.

The Lametas form thin and discontinuous outcrops occurring as narrow fringes along the margin of the Deccan trap in Lunavada State. Their mode of occurrence and their lithological characters are identical with those of the Lametas of Balasinor State.

Gabat.

A small outcrop of the Lametas has been mapped south of Gabat (23° 15′ : 73° 20′). The formation is composed of gritty, siliceous limestone often containing irregular, lenticular masses or pebbles of quartz and red jasper. The rock is locally used as a building material and also burnt as a source of lime.

The Bagh beds.

Lithology.

The Bagh beds are generally composed of a series of calcareous rocks underlaid by beds of sandstone, the characters of the component beds being variable. Occasionally there are beds of conglomerate, more or less calcareous, forming the basal members of the series. Marine fossils are usually found in the uppermost limestone beds. The maximum thickness of the series usually does not exceed 60 or 70 feet, though further south, in Rajpipla State, these beds are said to have attained an enormous thickness,[1] often exceeding a thousand feet.

Distribution.

Thin, lenticular, disconnected outcrops of the Bagh beds occur as narrow fringes along the margin of the Deccan trap in the Jhabua and Alirajpur States of the Central India Agency and Vajiria, Agar, Naswadi, Boriad and Chhota Udepur States of the Rewa Kantha Agency.

[1] *Mem. Geol. Surv. Ind.*, XXXVII, Pt. 2, pp. 170-172, (1908).

Well preserved lamellibranch and gastropod shells have been found in many places in the Bagh beds of Jhabua.

Fossils.

Of the lamellibranchs the following genera, all of marine habit, have been found in the collection, *Cardium*, *Macrocallista*, *Protocardium*, *Astarte*, *Mactra* (?), *Aucella* (?), *Grotriana* and *Crassinella*.

The following specific identifications have been made :—

Protocardium pondicherriense d'Orbigny.
Cardium (*Trachycardium*) *incomptum* Sowerby.
Macrocallista cf. *sculpturata* (Stol.).
Grotriana cf. *jugosa* Forb.
Crassinella cf. *planissima* (Forb.).

Of the gastropod fossil shells one could be specifically identified as *Turritella multistriata* Reuss. With the indistinct shells of *Turritella*, several shells of the order *Pulmonata*, family *Auriculidæ*, have also been noticed. The bulk of the fossils are marine, with the exception of the pulmonate shells.

Well preserved fossil shells belonging to the Lamellibranchia, Gastropoda, Bryozoa and Echinoidea have been found in the Bagh beds of Alirajpur. The following identifications have been made :—

Lamellibranchia.—*Cardium* (*Trachycardium*) *incomptum* Sowerby, *Crassinella* cf. *trigonoides* (Stol.). *Macrocallista*, *Mactra*, *Nucula*, *Ostrea*, *Protocardium*.
Gastropoda.—*Turritella* (*Zaria*) *multistriata* Reuss, *Melania*.
Echinoidea.—*Cidaris*.
Bryozoa.

Indeterminate lamellibranchs belonging to the genus *Ostrea* have been noticed in the calcareous shale beds in the Boriad exposures.

History of the age of the Bagh beds established by previous workers in the Narbada Valley.

The earliest collection from the Bagh beds was made in 1857, near Bagh, by Keatinge and Blackwell, who recorded their Cenomanian age. The collection was examined in 1865, by P. Martin Duncan[1], who stated that the echinoids are mostly identical with the species found in Europe in the Upper Greensand (Cenomanian). From

[1] *Quart. Journ. Geol. Soc.*, XXI, p. 349, (1865).

a general review of the mollusca and the echinoderms collected by Keatinge, Blackwell and Bose from the Bagh beds, Duncan[1] assigned a Cenomanian age to the fauna. P. N. Bose,[2] in the course of his geological work in the Narbada Valley, divided the marine Cretaceous of the area into three divisions : (A) Nodular limestone, (B) Deola and Chirakhan marl, (C) Coralline limestone, and tentatively classified the three divisions with the Utatur, Trichinopoly and Ariyalur stages of the Cretaceous of South India. Duncan,[3] however, observed that the three divisions of the Bagh beds established by Bose are conformable in their stratification and are characterised by the presence of common species of *Hemiaster cenomanensis* and *Hemiaster similis* and others which are characteristic Cenomanian forms. He further remarked that Bose's correlation of the Bagh beds, being based on rough identification of the fossils, cannot be of much stratigraphical value. In the course of his work in the Narbada Valley, Blanford[4] noticed marine Cretaceous fossils, and from field observations and general faunal assemblage regarded the Bagh beds as of the same age as the fresh-water Lametas, corresponding in age in Europe with the Aptian to Cenomanian. Vredenburg[5] regarded the three divisions of the Bagh beds established by Bose as successive facies of a single palæontological stage. From his field observations in the Dhar Forest, Central India, Vredenburg[6] corroborated Blanford's views that the Lametas are of the same age as the Bagh beds, the former being deposits laid down in fresh water on the Gondwana Continent, whilst the latter are those formed at the same time in the adjoining sea. From an examination of a collection of ammonites made by Bose from the Bagh beds, Vredenburg[7] assigned an age to the fauna ranging from the Gault to Lower Senonian. Vredenburg observed that the presence of *Placenticeros mintoi* in the Bagh fauna is not inconsistent with the attribution of the Bagh beds to the Cenomanian. In the course of the geological survey of the Jhabua State in 1909, Mr. H. Walker and Dr. A. M. Heron noticed marine fossils in the Bagh beds, containing specimens of *Rhynchonella* and some lamellibranchs, gastropods and bryozoa, in sheet 46 J/10, 14, which were found to join up with similar formations mapped

[1] *Rec. Geol. Surv. Ind.*, XX, pp. 81-87, (1887).
[2] *Mem. Geol. Surv. Ind.*, XXI, p. 135, (1884).
[3] *Rec. Geol. Surv. Ind.*, XX, pp. 81-87, (1887).
[4] *Mem. Geol. Surv. Ind..*, VI, p. 132, (1863-64).
[5] *Rec. Geol. Surv. Ind.*, XXXVI, p. 110, (1907-8).
[6] *General Report, Geol. Surv. Ind.*, p. 20, (1902-3).
[7] *Rec. Geol. Surv. Ind.*, XXXVI, pt. 2, p. 109, (1907).

by the authors in the adjoining western sheet 46J/2,6. From an examination of a collection of echinoids from the Bagh beds Fourtau[1] assigned an Albian age to the fauna. The results of recent researches of Von Heune and Matley[2] on the Dinosaurian remains in the Lametas of Jabalpur and Pisdura in the Central Provinces, definitely fix the age of the Lametas, the fresh water equivalents of the Bagh beds, as ranging in age from the Turonian to Upper Senonian. A general review of previous works shows therefore that from a study of their contained echinoid fauna, the Bagh beds of the type area were regarded as Cenomanian by Duncan, which was subsequently confirmed by Vredenburg on the evidence of the ammonite fauna. The results of recent investigations on the Bagh fossil fauna from the Jhabua and Ali Rajpur States, which has been found to contain several typical South Indian Upper Cretaceous forms, namely, *Protocardium pondicherriense*, *Cardium* (*Trachycardium*) *incomptum*, *Macrocallista* cf. *sculpturata*, *Turritella* (*Zaria*) *multistriata*, suggest that the Bagh fauna probably ranges up to Upper Senonian. The presence of characteristic Utatur forms in the Bagh fauna, namely, *Grotriana* cf. *jugosa* and *Crassinella* cf. *planissima*, shows that the beds range down to the Cenomanian. The probable age of the Bagh beds, as established from the examination of the Bagh fauna, appears to be Cenomanian to Upper Senonian.

The Nimar sandstone.

Gritty sandstone, corresponding, both in its lithology and mode of occurrence with the Nimar sandstone of P. N. Bose[3], has been recorded south-east of Pavagarh Hill (22° 26′ : 73° 32′). The sandstone unconformably overlies the Aravalli schists and phyllites and is overlain by the Deccan trap. The formation is almost horizontal and is composed of pinkish sandstone with porcellanic jasperoid rock, associated with ferruginous conglomeratic beds containing pebbles of quartz and chalcedony. No fossils have been found in it. The grit is extensively used as building stone, especially in the ruined city of Champaner, the capital of the old Mahommedan Kingdom of Gujarat. Small patchy outcrops of these gritty sandstones, associated with conglomeratic beds, occur north of Bhamria (22° 24′ : 73° 36′).

Pavagarh Hill.

[1] *Rec. Geol. Surv. Ind.*, XLIX, pt. I, (1918).
[2] *Pal. Ind., New Ser.*, XXI, Mem. I, (1933).
[3] *Mem. Geol. Surv. Ind.* XXI, Pt. 3, p. 23, (1884).

THE DECCAN TRAP.

A profusion of dark grey basalt, the Deccan trap lava flows, covers an extensive area along the eastern margin of the area under description. Several outliers of the trap are also seen in the central tracts of the area, mainly occupied by the Aravalli schists and phyllites. Innumerable detached outliers of the Deccan trap have also been recorded on the alluvial plains in the west of the area.

Distribution.

All over the eastern area, the Deccan trap is generally massive or finely crystalline and almost, as a rule, non-vesicular. It weathers into rounded, dark boulders and gravels, and finally yields black, highly fertile soil.

Lithology.

The rock is characterised by general homogeneity of composition and compactness of texture. Felspars, generally occurring as small laths, augite and opaque grains of iron ores are the constituent minerals.

The Deccan trap in the central area, occurring along the western frontiers of the Dohad and Jhalod *talukas* of the Panch Mahals district, is generally fine-grained and compact. More or less porphyritic types have also been occasionally noted. No vesicular nor amygdaloidal types have been seen in the field. Under the microscope the finer type shows (44/136; 22080) a finely crystalline texture. Felspars in small laths, augite and opaque iron ores are the constituents. Fairly large felspar phenocrysts have been seen to occur in the porphyritic type of the basalt. Under the microscope the rock (44/137; 22081) shows tabular phenocrysts, as well as well-defined laths of plagioclase felspars, with polysynthetic twinning after the albite law, the tabular patches showing broad lamellæ. The pyroxene occurs as small prisms, and is mostly non-pleochroic. The average extinction angle is about 45°. This mineral is often partly replaced by alteration products, both chloritic and serpentinous materials. Iron ores are present in grains and blotches. Patches of glassy base are also noticeable in the thin section. These vary in colour from brownish opaque to more or less clear yellow and show weak double refraction, possibly due to devitrification.

Of the numerous outcrops of the Deccan trap in the alluvial plains of the west, those occurring at the western frontiers of Lunavada and Balasinor States may be taken as representative. The rock is characterised by general homogeneity of composition and

compactness of texture. Slightly vesicular instances have, however, been occasionally noticed. Near Hothwad (23° 1' : 73° 17') the vesicular cavities in the trap have been found to be filled with calcite and zeolites, mostly stilbite (46/515). The basalt is generally holo-crystalline and is composed of plagioclase felspar, mostly labradorite, occurring as small laths, granular or platy pyroxene and grains of opaque iron ore. The rock is dark in colour and weathers into brownish and greenish boulders and gravel. These finally yield the dark, highly fertile, black cotton soil. The lava heaps west of Hothwad (23° 1'; 73°·17') often contain a somewhat porphyritic type. (46/516). Under the microscope it shows porphyritic olivine much traversed by cracks filled with green serpentinous decomposition products, greenish non-pleochroic pyroxene, often showing imperfect cleavage traces, and small laths and needles of plagioclase felspar. Spots of magnetite and small patches of chlorite also occur in fair abundance. The rock is a typical olivine-basalt.

No intertrappean beds have been noticed anywhere in the area under review, and it has not been possible to divide up the Deccan trap into distinct individual flows, nor to gain any information as to its age, except that it is post-Cretaceous.

POST-TERTIARY DEPOSITS.

Laterite.

Several instances of lateritic cappings on the trap have been noticed. These are irregular in their occurrence and do not show any considerable thickness. The laterite is indefinite in its composition, the limonitic and aluminous ingredients ever varying. In colour it varies from light red to dark brown.

Kankar.

Nodular, concretionary calcium carbonate is often met with in the soil on the crystalline areas adjoining the trap. The nodules owe their origin mainly to the calcareous solutions derived from the decomposition of trap.

Soil.

Dark grey cotton soil covers the elevated plains adjoining the trap mounds and ridges. It is extremely fertile and prosperous agricultural villages flourish on it.

Over the metamorphic regions the alluvial mantle varies widely in thickness. The richness of the soil is also variable. The granite and gneisses on disintegration yield rather poor sandy soil. The

crumbling schists, on the other hand, are invariably covered with fertile soil derived from their own disintegration and support rich vegetation.

ECONOMIC RESOURCES.

Bauxite.

A rich deposit of bauxite has been recorded near Taibpur (23° 2′ : 73° 4′) in the Kapadvanj *taluka* of Kaira district in association with the Ahmednagar sandstone. This deposit of bauxite was formerly worked by Messrs. Killick Nixon and Co., of Bombay, Managing Agents of the Shivrajpur Mines Syndicate, who have stopped the work temporarily.

Building materials.

Generally the Aravalli limestones of the area are too much broken and ramified with secondary siliceous veins to be of any use as a building stone. The thick bands of limestone at the northern frontier of Jambughoda State (Narukot) contain small patches of crystalline marbles. Both white and tinted varieties occur. These should make a useful building stone.

Limestone.

The slabby calcareous bands occurring in the infratrappeans of Alirajpur, Jhabua, Lunavada and the small Mahi Kantha States are often quite suitable for building purposes.

The sandy bands in the infratrappeans are often excavated for building purposes, as well as for the manufacture of grindstones.

Sandstone.

Extensive occurrences of slate have been seen in the argillaceous metamorphics of the Aravalli system. The most noteworthy occurrences are in the Jhalod *taluka* of the Panch Mahals district. The rock has developed jointing and yields slabs of varying sizes in abundance. Slabs measuring up to 12 feet by 4 feet have been noticed. The thickness varies between three and six inches. Tiles of irregular size and varying thickness are also available in the area.

Slate.

Fire-clay.

Fire-clay has been recorded near Derol railway station, (22° 38′ : 73° 28′) Panch Mahals district, in association with infratrappean

sandstones. The clay is refractory at 1,400°C. and does not shrink on firing. Its plasticity is rather poor. The occurrence is confined to a small area.

Galena.

A deposit of galena has been recorded near Khandia (22° 19′ : 73° 33′) in the Bhamria State, in the Aravalli phyllites and schists. The ore-body occurs in irregular thin veins and stringers intimately associated with quartz-veins intruding the schists. The irregularly lenticular occurrence and soil-covered condition of a considerable portion of the metalliferous zone render it difficult to be definite about the prospects of the deposit. A specimen of galena from the quartz-galena lode assayed in the Geological Survey Laboratory gave 18·16 oz. of silver per long ton.

Iron-ores.

Iron-ores have been recorded in Jambughoda State in the hematite-quartzite hills about 1½ miles south-west of Jambughoda (22° 22′ : 73° 44′). Specular iron-ore occurs in association with phyllites and quartzite around Jambughoda. These occurrences are not of economic potentiality, the deposits being small.

Manganese-ores.

Manganese-ore bodies of varying size and potentiality have been known to occur in the southern tracts of the Panch Mahals district as well as in the Jhabua State of the Central India Agency and the Chhota Udepur and the Narukot States of the Rewa Kantha States Agency.

These invariably occur in association with the ancient metamorphics, the Aravalli schists and quartzites of the area, as irregular nests and lenticular bodies. The most important of these deposits are those worked at Kajlidongri, Shivrajpur and Pani mines.

Jhabua State.

Of the manganese occurrences in Jhabua the two deposits of considerable economic importance, namely the Kajlidongri and the Rambhapur deposits, were examined by Sir L. L. Fermor in 1905, and several other deposits were subsequently reported upon by Mr. H. Walker and Dr. A. M. Heron in 1907.

All these have been exhaustively dealt with by Sir L. L. Fermor n his memoir on the Manganese-Ore Deposit of India.[1]

The Kajlidongri deposit is situated five miles to the W.N.W. of Meghnagar (22° 54′ : 74° 32′) station of the B.B. and C.I. Railway. It forms a low ridge rising to nearly 70 feet above the ground level, running with a strike of N. 30°W. for a distance of about 1,000 yards. Psilomelane, pyrolusite and braunite form the main bulk of the ore-body.

The Rambhapur deposit lies immediately to the north-west of Rambhapur town (22° 55′ : 74° 29′) and forms a low mound running N. 30° W. for nearly 250 yards along the line of strike of the Kajlidongri deposit, with which it is probably genetically connected. Pyrolusite, psilomelane and braunite are the main ore-minerals of this deposit. Kajlidongri and Rambhapur are no longer worked.

Manganese ores at Amlamal (23° 0′ : 74° 25′) occur in a steeply folded fine-grained reddish quartzite and appear to be very limited in extent.

At Nagankheri—Mandli (22° 45′ : 74° 39′) manganese minerals are included in siliceous boulders occurring as a mound approximately 20 feet high, 30 feet wide and 100 feet long. The occurrence is very limited in extent.

Low grade ore-bodies interlaminated with quartz have been recorded near Pitol. (22° 47′ : 74° 28′). The occurrence forms a low mound about 140 yards long.

A new occurrence is near Mandli (22° 57′ : 74° 24′). The ore is associated with vein-quartz and grey calcite. Massive psilomelane forms the bulk of the ore. Crystalline aggregates of braunite, hollandite with rhodonite, and piedmontite also abound. The ore body is irregular in its occurrence and no data for the estimation of the amount accessible for exploitation are available.

Shivrajpur.

Sir L. L. Fermor examined the manganese occurrences of Shivrajpur in 1905. The ores are irregularly distributed in the Aravalli slates and quartzites and are probably replacement products. The ores consist of pyrolusite, psilomelane and braunite. The quality of the ore is rather variable

[1] *Mem. Geol. Surv. Ind.*, XXXVII, Pt. 4, pp. 651, 679, 687-9, (1909).

owing to the residual patches of the original quartzite and slate that have escaped replacement.

A new occurrence of manganese ore has been noted in the Aravalli schists of the Panch Mahals district. This lies about three miles north of the Anas railway station of the B. B. and C. I. Railway. The ore consists of pyrolusite, psilomelane and wad. These occur as local bands and lenticles along with quartzite interbanding in the country-rock.

Pani Mines.

Manganese-ore deposits of considerable economic importance occur near Pani (22° 27′ : 73° 47′) in Chhota Udepur State in the midst of the Aravalli phyllite and quartzites. The ore body is mainly pyrolusite and appears to be the result of replacement of the quartzite by oxides of manganese. Occurrences of particularly rich ores have occasionally been found to contain as much as 95 per cent of pyrolusite. Mr. G. V. Hobson examined the occurrences in 1924[1].

Jothvad.

The manganese ore deposits near the village Jothvad (22° 24′ : 73° 44′) in Narukot State were examined by Sir L. L. Fermor in 1905.[2] These occur about half a mile north of the village, in a small hill striking north and south for about half a mile and rising about 150 feet above the general level of the surrounding plains. The hill is composed of an inlier of intensely folded Aravalli gneisses surrounded and traversed by porphyritic biotite-granite. Rich in variety of very interesting manganese minerals as this occurrence is, it has been found to be of but little economic importance.

Mica.

The pegmatite dykes in the granite of the area often contain muscovite in considerable amount. The mica is stainless but the flakes are generally small in size.

[1] *Mem. Geol. Surv. Ind.*, XXXVII, Pt. 4, p. 646, (1909).
[2] *Rec. Geol. Surv. Ind.*, LIX, Pt. 3, pp. 352-354, (1926).

LOCALITY INDEX.

Name.	Latitude.		Longitude.		Page.
	°	′	°	′	
L					
Limkhera	22	50	74	0	186.
Lunavada	23	8	73	37	164, 168, 171, 184–186, 189, 190, 193, 195, 199, 201.
M					
Mandli	22	57	74	24	203.
Meghnagar Stn.	22	54	74	32	203.
Mekhar	22	58	73	48	208.
Metral	23	4	73	49	187.
Morwani	23	46	74	34	176.
N					
Nagan Kheri—Mandli	22	45	74	39	203.
Naswadi	22	3	73	44	195.
P					
Padaria	23	22	74	18	180.
Pani	22	27	73	47	202, 204.
Pavagad (Pavagarh)	22	26	73	32	167, 198.
Pipalkunt	23	48	74	34	178.
Pipodara	22	43	74	3	186.
Pitol	22	47	74	28	203.
Potla	23	11	74	26	180.
R					
Rambhapur	22	55	74	29	182, 189, 202, 203.
Roenia Naika	23	14	74	18	193.
S					
Samoi	22	39	74	27	208.
Sanjeli	23	4	73	58	164, 168, 193.

LIST OF PLATES.

TIN-TUNGSTEN MINERALISATION AT MAWCHI, KARENNI STATES, BURMA. BY J. A. DUNN, D.Sc. (MELB.), D.I.C. (LONDON), F.N.I., F.G.S., *Petrologist, Geological Survey of India.* (With Plates 6 to 12.)

CONTENTS.

INTRODUCTION.

Until recently, very little was known about the complex tin ores of Karenni and there is no published detailed geological literature on the subject. Mr. J. J. A. Page and Mr. H. Walker, both of the Geological Survey of India, visited Mawchi in 1909 and 1915-16 respectively. Walker's report, which was published by the Burma Government,[1] was concerned more

[1] H. Walker, Report on the Mawchi Mine, Bawlake State, Karenni, Burma. Government Press, Rangoon.

with ore reserves and assay values than with detailed geological and mineralogical descriptions. Although we have a broad idea of the geology of the Mawchi area, no detailed maps have yet been published.

Early in 1935, Dr. J. C. Brown suggested to me that a mineragraphic study of the complex tin-wolfram ores of the Mawchi mine would supply interesting information. Fortunately, towards the end of the same year, Mr. G. V. Hobson, until lately of the Geological Survey of India, joined the staff of Mawchi Mines Ltd., and, by courtesy of the General Manager he was able to send me specimens from time to time.

It was hoped that Mr. Hobson and I would be able to write a joint account on the Mawchi mineralisation, but stress of work has prevented Mr. Hobson from carrying out our original object. The mineragraphic work was finished early in 1936, and as I am about to proceed on leave, and other work will undoubtedly require attention on my return, it has been thought advisable to publish the results of my petrological studies immediately. However, although this account will lose by its lack of detailed field descriptions, its prior submission to Mr. Hobson for comment will, I hope, preclude the intrusion of serious errors.

GEOLOGY.

Country rock.

Mr. G. V. Hobson describes the Mawchi area as consisting of argillites and fine sandstones with some limestones, intruded by a large granitic mass. The argillites show no cleavage. The tin-wolfram deposits occur in each of these rock types, but with one exception the veins very rapidly die out on meeting the limestone. In the upper horizons of the mine, slates are the principal country rock, whilst in the lower horizons the lodes are in granite.

The limestones are fine-grained and have been somewhat recrystallised. Some appear to be slightly carbonaceous. Three specimens were analysed as in Table 1.

Specimen A is a dark grey limestone containing tremolite and much fine quartz; secondary sulphides are scattered throughout. Specimen B is quite a fine-grained rock, whilst C is a pure white saccharoidal limestone. In consequence of their metamorphic character they might aptly be described as marbles.

TABLE 1.

—	A.	B.	C.
SiO_2	21·58	0·10	0·14
$Fe_2O_3 + Al_2O_3$	6·43	0·30	0·35
CaO	37·95	55·81	54·85
MgO	3·68	0·38	0·96
MnO	0·01	0·01	0·01
K_2O	0·91	0·02	0·05
Na_2O	0·27	0·21	0·17
Loss on ignition	26·74	43·30	43·35
H_2O + ...	1·13	0·22	0·19
H_2O —	0·82	0·06	0·02
S	0·55	*Nil*	*Nil*
P_2O_5	0·02	*Nil*	*Nil*
Carbonaceous matter	0·33	*Nil*	*Nil*
	100·42	100·41	100·09
Specific Gravity	2·700	2·732	2·667
Analyst—Mahadeo Ram.			

Mineralisation at Mawchi is obviously associated with the granite, which frequently contains a noticeable amount of cassiterite. Veins of aplite and pegmatite traverse the granite, as also do tourmaline-quartz veins, in which there may be a little cassiterite. Fine-grained "segregations" containing tourmaline, cassiterite, wolfram and scheelite (the latter replacing wolfram) occur quite commonly. The granite is rather variable both in texture and mineral assemblage. Occasionally it is banded or gneissic, especially the tourmaline variety. Kaolinisation has been widespread, and this is by no means an effect of weathering, but appears to be largely a

late magmatic change due to the removal of alkalies by either volatiles or hydrothermal solutions. It was necessary to impregnate almost every specimen with bakelite before thin sections could be made, using kerosene as a lubricant.

Oligoclase and orthoclase are present in variable amounts, but the former is typically the more abundant. Orthoclase is usually more severely kaolinised than is oligoclase. Oligoclase is often idiomorphic, and is earlier than orthoclase. Evidence of resorption of oligoclase was noticed, quartz replacing oligoclase crystals. Quartz is usually only in subordinate amounts, but is often quite abundant in the more sodic varieties. Most of the quartz shows a curious persistent relation to the felspars ; it followed oligoclase but preceded orthoclase in the crystallisation sequence. A later fine-grained quartz does occur occasionally, interstitial to orthoclase, but the normal sequence was undoubtedly :—oligoclase, quartz, orthoclase. Very rarely the orthoclase shows a graphic texture with quartz. Sometimes microcline is observed in fresh specimens —it is possibly abundant, but obscured by kaolinisation. Porphyritic varieties usually consist of oligoclase phenocrysts in an oligoclase-quartz-microcline groundmass.

The rock is a tourmaline-granite throughout. Sometimes tourmaline is present to the exclusion of other ferromagnesians. Biotite occurs in only a few specimens, and, with the exception of a little green hornblende in one specimen, appears to be the only primary ferromagnesian mineral present in these rocks. Usually the brown biotite is somewhat altered to chlorite. The tourmaline is frequently seen to replace other minerals ; in those specimens in which it is the only ferromagnesian present, tourmaline possibly originally replaced first biotite and then continued growth by replacing felspar. It is both blue and brown in colour, and is occasionally zoned. Sometimes the centre of the tourmaline may be a well defined crystal, which has continued growth as an outer zone of blue tourmaline replacing felspar and quartz. A common position of replacement by tourmaline is at the interface between two minerals such as felspar and quartz.

Muscovite is entirely secondary, usually replacing felspars ; no primary muscovite was observed. It frequently occurs as radiating rosettes, especially when it shows the pink-green pleochroism of lepidolite. It is noticeable that the muscovite tends to replace oligoclase rather than kaolinised orthoclase. Muscovite and

tourmaline are frequently closely associated and muscovite veins the tourmaline.

Fluorite, usually purple in colour, is seen in several specimens, interstitial to felspars and quartz, and usually associated with fine muscovite. It commonly replaces oligoclase.

Calcite is present in the more altered types, as are also minute prisms of topaz. Such more altered types contain a large amount of muscovite and secondary quartz as well as pyrite. Pyrite and magnetite replace each other, but it is not clear in which exact order. Epidote is occasionally present.

Grains of cassiterite are found in many of these granite specimens. It is often zoned and may show a red to colourless or pale green pleochroism. It is usually interstitial to the quartz and felspar, and is more closely associated with tourmaline, muscovite and fluorite. Occasionally it appears to replace felspar and quartz. In some cases, where the granite has been crushed and the cassiterite appears to have replaced crushed quartz, it is obviously later than the crushing. Analyses of three specimens of this granite are given in Table 2.

No. 8.—A fresh fine medium-grained tourmaline granite. Notwithstanding that fluorine is not recorded in the analysis, a few minute grains of fluorite can be seen in thin section. Cassiterite can also be determined in the thin section.

No. 19.—A fresh fine medium-grained tourmaline granite with a little biotite. Zoned cassiterite is present in the thin section, although not determined in the analysis.

No. 20.—A slightly kaolinised coarse-grained porphyritic granite with much biotite and epidote, and a little hornblende and apatite. Cassiterite is also present.

Ore bodies.

A number of lodes have been worked at Mawchi. As long ago as 1916, Walker recorded seventeen veins varying up to five feet in thickness, and ten were of a payable nature. Workable veins now number twenty-seven, some of which, in places, are double or treble veins, thus increasing the actual number considerably. They strike N. N. E. over a length of a few hundred feet and are usually almost vertical. Cropping out on the surface of the hill, they have been readily worked from adits.

TABLE 2.

—	8.	19.	20.
SiO_2	79·50	75·72	67·40
TiO_2	*Nil*	*Nil*	trace
Al_2O_3	12·73	16·21	15·19
Fe_2O_3	0·40	0·71	4·70
FeO	0·35	0·43	0·71
CaO	0·22	0·11	2·66
MgO	0·10	0·26	0·06
MnO	0·08	0·08	0·06
BaO	0·01	trace	..
K_2O	2·66	3·26	4·60
Na_2O	3·38	2·86	3·50
Li_2O	*Nil*	*Nil*	..
P_2O_5	trace	0·01	0·19
CO_2	0·10	0·08	0·16
B_2O_3	0·25	trace	*Nil*
F	*Nil*	trace	..
H_2O at 110°C	0·10	0·14	0·21
H_2O above 110°C	0·37	0·17	0·40
SnO_2	0·17	..	0·08
TOTAL	100·42	100·04	99·92
Specific Gravity	2·57	2·59	2·69
	Analyst Mahadeo Ram.	Analyst R. Dutta Roy.	Analyst R. Dutta Roy.

The lodes are mainly of cassiterite, wolfram and quartz, with calcite as quite a common gangue mineral. The grade varies very considerably from place to place in the veins, but mill heads average

just below 3 per cent. A coarse banding is occasionally noticeable as a result of an arrangement of the minerals parallel to the vein walls. The origin of a curious vein variety described by Mr. Hobson as a " sand lode " is difficult to interpret; the lode channel here is occupied by fine loose grains of quartz with cassiterite of a sandy nature. It calls to mind the unusual occurrence at Mount Bischoff in Tasmania, where in places porphyry dykes were attacked during mineralisation and the felspars removed as well as much of the quartz, leaving merely a loose angular cassiterite-quartz-sand which filled the dyke space completely.[1]

The lode minerals show little disturbance under the microscope, apart from slight movement which permitted later minerals to form veins along cracks in earlier minerals. The platy calcite often shows considerable signs of crushing. In the hand specimens slickensided faces are sometimes seen.

MINERAL DESCRIPTIONS.

This work was completed before the installation of the lead lap polishing machine in the Geological Survey Laboratory. Most of the microphotos accompanying this account were taken on surfaces polished on cloth laps. The ores and gangue minerals are described separately, and in the order of decreasing importance.

Ore minerals.

Only the mineragraphic descriptions of cassiterite, wolfram, scheelite and molybdenite are given here; those for the sulphides are well enough known to need no repetition.

Cassiterite.—Usually the cassiterite in these ores is quite coarse-grained but fine grains may be seen in polished sections. In quartz and calcite it often shows well developed crystal faces, but where associated with wolfram it is commonly interstitial to the latter and shows no crystal boundary (Pl. 6, fig. 1). The mineral is readily detected by its dark yellowish brown colour and great hardness. A large grain gave a specific gravity of 6·92. As a result of crushing and the brittle character of the mineral it often crumbles very easily. In thin sections it is beautifully zoned (Pl. 10, fig. 3) and exhibits a red to pale green pleochroism.

[1] J. A. Dunn, 'The economic geology of the Mount Bischoff tin deposits, Tasmania, *Econ. Geol.*, XVII, pp. 162, 163, 166, 167, 174, 176, (1922).

It is more difficult to polish this than perhaps any other mineral. With cloth polishing it is almost impossible to obtain any considerable area of the mineral free from deep pits and grooves, and, with its high relief, flat, smooth surfaces are rare. However, better results are obtained by polishing on lead laps, but even then the mineral's brittleness gives rise to difficulties. Hardness: G+. Reflectivity: about 11. Colour: grey, sometimes zoned, and multiple twinning shows up at times as a result of slight pleochroism. On smooth surfaces polished on lead laps, a prismatic cleavage is sometimes seen. A yellow inner reflection is occasionally noticeable under polarised light. Anisotropism: moderate, colours usually obscured by the strong variegated (mainly amber yellow) inner reflection.

Etch tests:
- Negative.—HCl, HNO_3, aqua regia, H_2O_2, $H_2O_2 + H_2SO_4$, $HgCl_2$, $FeCl_3$, KOH, KCN, $SnCl_2$.
- Positive.—A drop of HCl and a fragment of metallic zinc gives a film of metallic tin over the surface.

Wolfram.—This mineral is very abundant throughout all of these ores. It is usually coarse-grained, often forming laths several inches in length with well defined crystal faces in quartz (Pl. 6, fig. 3) and in many cases grew inwards from a thin selvage along the vein walls. Without exception it retains its prismatic form against cassiterite (Pl. 6, figs. 1 and 2). The prismatic cleavage is so well developed that the mineral crumbles readily on breaking. An analysis on carefully hand-picked material, which previous microscopical examination had shown to be free from replacing scheelite, gave the following results:—

TABLE 3.

WO_3	70·92
FeO	9·90
MnO	13·58
MgO	3·12
CaO	0·08
SnO_2	0·27
SiO_2	0·36
Al_2O_3	0·58
H_2O+	0·04
H_2O-	0·22
	99·07

Analyst— R. Dutta Roy.

Assuming the correctness of this analysis the high percentage of MgO is surprising in view of the care with which the fine grains of wolfram were hand-picked. It can only be assumed that some tourmaline escaped detection in picking. But even if this were so the amount of SiO_2 and Al_2O_3 should be greater than that determined.

The mineral polishes rather well, with few pits; the prism directions are smoother than the basal. Hardness: About D, scratched by a needle, shows a decidedly lower relief against cassiterite and against quartz. Reflectivity: about 18, with slight pleochroism noticeable only between adjacent grains. The reflectivity and colour are exactly the same as those of sphalerite, which is sometimes associated with the wolfram, and the two are distinguishable only between crossed nicols. The sphalerite in these ores always contains minute ex-solution droplets of chalcopyrite and sometimes of stannite. Colour: grey-white, with a hint of brown. Prismatic cleavage is often noticeable. Sometimes the mineral shows zoning with scheelite, apparently as a result of selective replacement by the latter. Anisotropism: moderate, colours are yellow and dark grey, sometimes with a hint of violet or green. A red inner reflection is noticeable between crossed nicols, particularly where the surface is not well polished.

Etch tests.—Negative.—HCl, HNO_3, aqua regia, H_2SO_4, H_2O_2, $H_2O_2+H_2SO_4$, $HgCl_2$, $FeCl_3$, KOH, $SnCl_2$.

Microchemical tests.—A bead test with sodium carbonate and sodium peroxide gives a bluish green colour with presence of Mn. This test is usually sufficient for Mn. Fe can be detected by the thiocyanate test, and W by the method described under scheelite.

Scheelite.—Although scheelite is so widely distributed throughout these ores, it is not usually detected in the hand specimen. However, occasionally a white material, interstitial to wolfram, can be diagnosed as scheelite. Its principle mode of occurrence is as a replacement product of wolfram, when it has almost the same colour as the latter. Where wolfram loses its easily separated cleavage and takes on a dull colour it is invariably found to be largely replaced by scheelite.

An unusual specimen was obtained from one of the veins. This was a brownish, rather, porous, and almost incoherent material, which had obviously been subjected to considerable leaching.

The properties of this mineral, as they appear under the ore microscope, have not been described previously. There is little question that the mineral is identified with greater ease by thin section, but as it is so commonly found in these wolfram ores, a knowledge of its properties under reflected light assists in the study of its relations with the other ore minerals. Its relation to wolfram is much more clearly seen in polished than in thin sections.

Scheelite takes an excellent smooth polish with no pits remaining. Hardness: D–, less than wolfram, the latter standing up slightly in relief from it. Reflectivity: about 10, just less than cassiterite, and difficult to compare owing to the latter's uneven surface, but best judged by strong screening. Its reflectivity is greater than that of any gangue mineral present. Anisotropism: completely obscured by the pale yellow and white inner reflection.

Scheelite shows two modes of occurrence, in one (much the more abundant) it replaces wolfram, and in the other it is interstitial to the latter. Sometimes the one is optically continuous with the other mode of occurrence, their reflectivity being identical, but the replacing scheelite may show a pale yellow inner reflection in contrast with the white of the interstitial scheelite.

Etch tests: Negative.—HCl, HNO_3, aqua regia, H_2SO_4, H_2O_2, $H_2O_2+H_2SO_4$, $SnCl_2$, KCN, KOH, $FeCl_3$, $HgCl_2$.
Positive.—No reagent yet tried.

Microchemical tests:—The mineral is fused as a minute bead with sodium carbonate and sodium peroxide, crushed on a glass slide and dissolved in a drop of distilled water. The solution is removed by a capillary tube and dropped on to a filter paper moistened with a drop of conc. HCl, then a drop of KCNS and $SnCl_2$ solution added, the typical blue colour of W developing. The test for Ca is scarcely necessary but can be done on the residue from the water solution. This residue is taken up in HCl, a drop of ammonium sulphide added, warmed, a drop removed by capillary tube to a fresh place on the slide, and a fragment of dihydroxy tartaric oxazone added, a white precipitate forming, but sometimes only after a lapse of several minutes.

Pyrite.—This mineral is fairly widely scattered throughout these ores. Usually in small grains, it frequently has quite well defined

crystal boundaries. In one specimen from near the junction of the Paunglaung Chaung and the Angyi Chaung, on the high ground north-east of Sheet No. 94 A/5, the pyrite has zonal layers which possess a slightly different colour, more creamy brown than the pale yellow of the pyrite. These layers are of just slightly lower hardness than pyrite, and have the same reflectivity and are isotropic. Etch tests are as for pyrite and microchemical tests were negative except for Fe and S.

Arsenopyrite.—Almost equalling pyrite in abundance, arsenopyrite is found in these ores to assume two forms. For the most part it occurs as rather coarse irregular grains, but in rare instances small needles of the mineral have been observed in chlorite (Pl. 8, fig. 3). The coarse grains commonly show twinning. A consistent excellent sulphur reaction indicates that löllingite is not present.

Molybdenite.—Flakes of molybdenite are commonly scattered throughout these ores. No example was observed of a molybdenite flake being enclosed in either a cassiterite or a wolfram crystal, but it is commonly interstitially arranged with respect to these minerals. It is often enclosed in quartz and in such sulphides as bismuthinite and galena (Pl. 9, fig. 3). Veinlike lines of molybdenite are invariably found to consist of a single contorted flake. Very commonly it occurs at the boundary between two minerals, but in such cases it appears that the original host mineral of the molybdenite has been replaced by later sulphides on one side of the flake.

Molybdenite polishes rather well notwithstanding its low hardness. Hardness: B, the softest of all the ore minerals. Reflectivity: varies widely, 30 along the basal direction (O), 15 in the direction of c' (E). This high reflection pleochroism is one of the diagnostic features of molybdenite. Colour: white and dark grey, according to direction. Anisotropism: very strong, white with pinkish tint. No internal reflection.

Etch tests:—Negative to all reagents. HNO_3 doubtfully positive.

Microchemical tests:—The test for Mo may be done exactly as for W, but the edge of the drop is red instead of the blue centre of W. Owing to the relative solubility of MoS_2 the mineral may be taken direct into solution with HCl instead of fusing first with a flux.

Galena.—Although scattered throughout these ores, galena is not abundant. In specimens polished on cloth, minute veinlets of galena in cassiterite are liable to be overlooked owing to the extreme difference in hardness of the two minerals, particularly if the cassiterite surface is deeply pitted and grooved.

Sphalerite.—Occasional coarse grains of sphalerite are seen, usually containing minute ex-solution droplets and veinlets of chalcopyrite and rarely of stannite. A very slight anisotropism, seen in a few grains, suggests that wurtzite is also present.

Sphalerite is very similar indeed to wolfram at first place under reflected light, as their colour and reflectivity are almost identical. They are, of course, readily identified under crossed nicols, and by the common association of chalcopyrite droplets in sphalerite.

Chalcopyrite.—Coarse grains of this mineral are relatively rare, but ex-solution droplets and veinlets in sphalerite are very abundant. Droplets of the mineral also occur in stannite.

Bismuthinite.—Most of the bismuthinite occurs as a fine intergrowth in galena, but occasional coarse grains have been determined. The optical and etch properties of this mineral were confirmed by micro-chemical reactions for Pb, Bi and S. No native bismuth was detected in these ores.

Covellite.—In addition to the covellite which had clearly replaced stannite and chalcopyrite, there are a few minute specks of covellite which cannot definitely be regarded as supergene, and may be hypogene.

Chalcocite.—This mineral, like covellite, replaces chalcopyrite, but is not common. All the chalcocite noted in these ores is definitely supergene.

Cerussite.—The galena has only very rarely been altered to cerussite. These three last supergene minerals usually occur together.

Tungstite.—The wolfram has occasionally been altered to a WO_3 ochre, a brown powder which sometimes has a structure reminiscent of wood-tin.

Gangue minerals.

Quartz.—Easily the greater part of these veins consists of coarse white quartz. There does not appear to have been any considerable silicification of the country rock. Like wolfram, the quartz often

grew inwards from thin selvages along the vein walls. A few small well developed crystals of quartz occur, with interstitial calcite, in the centre of the lodes.

Calcite.—In certain parts of the lodes calcite is the principal gangue mineral. It is white in colour with a remarkable silky sheen on the cleavage faces, and has a peculiar platy or almost acicular habit (Pl. 12, fig. 4); it readily disintegrates to a fine powder on rubbing. Under the microscope it is seen to be considerably crushed. Cassiterite occurs in this material as irregular crystals which fall away from their matrix on being touched. To obtain a polished section of such material thorough impregnation with bakelite resinoid was essential. The habit of this calcite is so unusual that its diagnosis was confirmed by analysis. A certain amount of fine quartz is present in each specimen, as well as a little sulphide; such quartz is irregularly replaced by the calcite (Pl. 12, fig. 3). The analysis was done on sulphide-free material:—

TABLE 4.

Insoluble (quartz)	7·74	per cent.
$Fe_2O_3+Al_2O_3$	0·36	,, ,,
CaO	48·57	,, ,,
MgO	1·29	,, ,,
Loss on ignition	40·04	,, ,,
TOTAL	98·00	,, ,,

Analyst—Babu Mahadeo Ram.

Tourmaline.—In the veins, both blue and brown tourmaline occur, but the blue variety is easily the more abundant. It occurs both as fine and coarse grains, and frequently shows quite well developed crystal faces. It is commonly associated with chlorite and muscovite, which may replace it (Pl. 10, fig. 4). A selvage which is sometimes found along the vein walls consists entirely of tourmaline.

Muscovite.—Including lepidolite and gilbertite. These are not particularly abundant in the vein material, and occur more particularly on the vein wall. The lepidolite shows the typical rose pink colour, whilst the fine-grained gilbertite is of a silvery white to silky green colour; both sometimes occur as radiating rosettes.

Coarse muscovite is very rare in the specimens examined; a curious pale greyish brown variety has been observed.

Chlorite.—A little chlorite occurs in the gangue, usually replacing and veining other minerals, but is more abundant in the vein walls.

Fluorite.—Although not detected in the more simple quartz veins, fluorite appears to be quite well distributed where the vein constituents are more complex, particularly where calcite, zoisite, garnet and beryl occur. It can be determined in the hand specimen by its usually distinctive purplish colour, although a green variety is sometimes seen, and its refractive index provides a rapid confirmatory test.

Beryl.—In certain places beryl is particularly abundant, and locally constitutes the greater part of the lode material. Once determined, it is readily distinguished in the hand-specimen. Usually it forms quite coarse crystalline aggregates with a typical pale blue colour. It is a variety low in alkalies, as suggested by its low refractive index, $\varepsilon=1{\cdot}576\pm{\cdot}002$ and $\omega=1{\cdot}583\pm{\cdot}002$.

Phenacite.—This rather rare beryllium silicate was detected in these ores under the microscope. In thin sections it is colourless and shows an excellent prismatic cleavage, the mineral being uniaxial, positive, $\omega=1{\cdot}650$, $\varepsilon=1{\cdot}665$. Some of the isolated mineral gave a good Be test.

Garnet.—A pale yellow garnet, apparently grossularite, was detected in two specimens from these veins. It occurs in a dense, banded vein material, one of the bands consisting almost entirely of grossularite and replacing calcite. The refractive index of the garnet is 1·745, and its specific gravity is 3·4.

Zoisite.—Quite abundant zoisite was detected in one specimen. The country rock of the vein at this point is marble, and it is probable that much of the vein here has replaced the country rock. The specimen consists of coarse orthoclase-cassiterite on one side, and of orthoclase, zoisite, fluorite and calcite on the other.

Orthoclase.—Occasionally orthoclase occurs as a principal constituent of the vein material, both in granite and marble country rock. It differs from the orthoclase of the granite in that it is coarse-grained and usually clear, although sometimes kaolinised. It is, however, replaced in turn by coarse zoisite, fluorite and calcite—the presence of these necessitated a refractive index determination to distinguish it from calcic plagioclase.

Kaolinite.—From one of the fault planes which intersect the granite in this area, a peculiar white, soft talcose material was analysed and proved to be of the kaolin group:—

TABLE 5.

SiO_2	49·32
Al_2O_3	34·65
Fe_2O_3	0·24
FeO	0·35
MnO	trace
CaO	0·88
MgO	0·40
K_2O	0·08
Na_2O	0·58
P_2O_5	*nil*
TiO_2	*nil*
H_2O above 110°C	9·53
H_2O at 110°C	3·45
TOTAL	99·48

Specific Gravity 2·510.
Analyst—R. Dutta Roy.

ORE DESCRIPTIONS.

Mineral sequence.

The accompanying sequence diagram (Fig. 1) has been constructed from a study of both polished and thin sections. The relationship of the minerals may now be discussed in the order of their deposition.

Mr. G. V. Hobson has found that garnet occurs quite commonly in the lower horizons of the mine, and, as a rule, in veins or parts of veins that are barren. Hence, in this collection of specimens selected to study the major ore minerals, garnet is rare and there is little on which to judge its position in the sequence, but it is clearly earlier than beryl and quartz. It occurs in a vein in No. 2 horizon in granite country with beryl and is replaced by calcite.

Zoisite, found in vein specimens from No. 1 horizon in marble country rock, is possibly a high temperature contact mineral and clearly preceded associated fluorite.

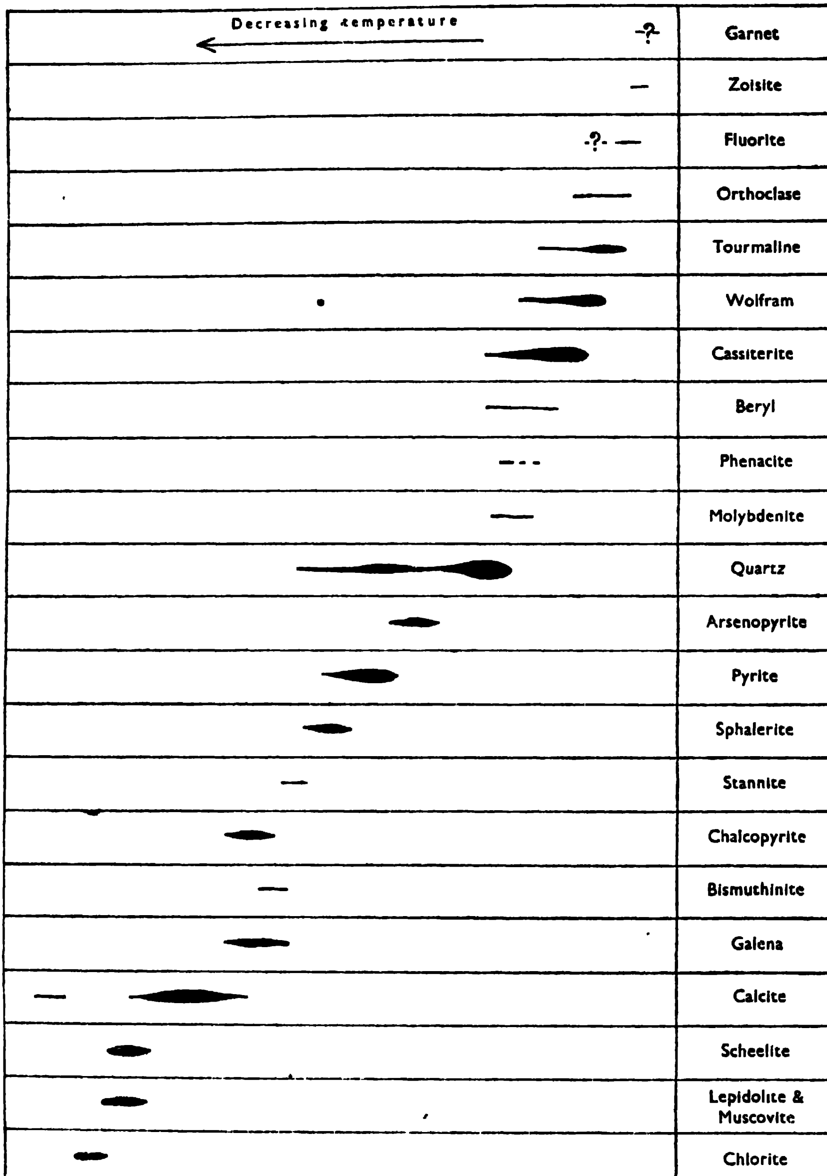

FIG. 1—Sequence and intensity diagram, Mawchi ore.

Fluorite was at first assumed to be late in the sequence, but, surprisingly, it was found to be one of the early minerals. It may have a much wider range than that indicated in the sequence diagram, but it is more closely associated with the earlier minerals than with the later, and its period of crystallisation was presumably brief; the mineral is not particularly abundant. It replaces orthoclase and is, in one place, veined by blue tourmaline, and in another by pyrite. Occasionally it is replaced by calcite.

The orthoclase of the veins in No. 1 horizon is clear and unaltered in contrast to the cloudy kaolinised felspars of the granite. It is replaced by cassiterite and calcite. It is sometimes apparently interstitial to cassiterite (Pl. 11, fig. 1) and the inference is that the two minerals crystallised more or less together.

Blue tourmaline is abundant; brown tourmaline is not seen so frequently. In every case tourmaline is closely related to cassiterite and wolfram. In some sections blue tourmaline was seen to have grown outwards from euhedral wolfram, and in one case it replaces the latter. It commonly shows euhedral outlines against wolfram (Pl. 6, fig. 3), and occasionally prisms of the mineral are included in the latter. Crystallisation of these two minerals obviously overlapped. Cassiterite sometimes shows euhedral outlines against tourmaline, but more often the tourmaline has well developed prismatic faces against cassiterite. It is sometimes replaced by quartz and muscovite (Pl. 10, fig. 4). Blue tourmaline has apparently been replaced by scheelite, but this may, at times, be a relict relation and the scheelite may have actually replaced wolfram which had previously replaced tourmaline.

Although wolfram and cassiterite are closely associated, in no case was either mineral found to replace the other. Wolfram shows a consistent euhedral form against cassiterite, the latter being usually interstitial to wolfram prisms, as if moulded upon them (Pl. 6, figs. 1 and 2). For the most part, then, it would appear that wolfram commenced crystallisation prior to cassiterite, so far as the formation of the veins is concerned. However, in one section a grain of cassiterite included in wolfram was definitely veined by the latter, the two sides of the vein dovetailing into each other. The evidence points to the two minerals crystallising closely in time, the wolfram preceding the cassiterite but deposition of the two overlapping.

Cassiterite in these ores displays its characteristic stability and is not usually replaced by other minerals. In only one or two cases was the mineral seen to be replaced by pyrite and by quartz. Very rare veins of galena (Pl. 10, fig. 1), scheelite and calcite have been seen in it. In contrast, wolfram has been widely replaced and veined by scheelite, and in places is veined and replaced by sulphides and such gangue minerals as quartz, mica and calcite.

Beryl occurs in lodes in granite country and is closely associated with cassiterite and early quartz. It is interstitial to cassiterite and even veins the latter (Pl. 11, fig. 2). Quartz appears to have followed beryl immediately, as it is slightly interstitial to it and occasionally replaces it. Beryl is replaced and veined by sphalerite, galena and muscovite; in one case, where scheelite had replaced laths of wolfram, the scheelite at the border had replaced and veined beryl along the latter's cleavage (Pl. 11, fig. 3).

Phenacite replaces tourmaline, and in one case minute prisms of the mineral radiate from a tourmaline crystal. It is veined and replaced by sulphides, carbonate and scheelite. It occurs in lodes in both slate and granite country.

Molybdenite appears to be the earliest of the sulphides. It commonly occurs as small thin flakes isolated in quartz or at the border of wolfram and quartz. It is replaced by calcite in one section, where it occurs as flakes in tourmaline, but the latter mineral has been largely replaced by calcite and micaceous material. In quartz and bismuthinite (Pl. 9, fig. 3) it often appears to form wavy veins, but these are really thin elongated, distorted flakes of the mineral; between crossed nicols they show the characteristic wavy extinction. along the length of the flakes. Molybdenite has the appearance at times of having formed at the interface between quartz and bismuthinite, but in such cases the later sulphide has usually replaced the quartz up to the molybdenite flake. Molybdenite flakes were seen in scheelite which had, however, replaced wolfram. The evidence, on the whole, indicates that it is earlier than quartz and other sulphides and that it is closely associated with cassiterite and wolfram, apparently immediately succeeding the latter.

The early phase of mineralisation closed with the deposition of a large amount of white quartz. This replaced some of the earlier minerals such as wolfram (Pl. 7, fig. 2)—in one specimen this replacement was so complete that only the outline of the original mineral

was left. The relation of quartz to cassiterite is well illustrated around a vugh in a narrow vein. Fine cassiterite occurs along the wall of the vein, then quartz, then coarse crystals of cassiterite have grown out into the vugh, whilst cutting across such individual crystals minute quartz veinlets may be seen.

On the whole it might be said of this first phase of mineralisation that, apart from fluorite and zoisite, the minerals show little tendency to replace one another, but mainly separated out as a mineral aggregate in the form of veins which exerted comparatively little replacing effect on the country rock. It should not be understood that this tin-tungsten phase was sharply demarcated from the later mineralisation. Quartz continued to be deposited and veinlets are found to penetrate later minerals in succession.

Further mineralisation gave rise to the deposition of arsenopyrite and pyrite. Well defined veinlets of pyrite occasionally cut across arsenopyrite (Pl. 8, fig. 1). In one specimen quartz veins cut across arsenopyrite, whilst pyrite veins intersect the quartz (Pl. 7, fig. 3), clearly indicating an interval between the two sulphides. Although neither mineral was seen to show a euhedral boundary against the other, pyrite is frequently euhedral against quartz and other gangue minerals. Veins of pyrite occur in tourmaline (Pl. 7, fig. 4) and orthoclase, and are especially common in wolfram; such veins often also contain chalcopyrite. Pyrite frequently accompanies quartz veinlets in wolfram. Both arsenopyrite and pyrite may be found along the interfaces between wolfram, cassiterite and quartz. Both sulphides are sometimes veined and replaced by chalcopyrite, quartz, calcite and other gangue minerals.

Sphalerite is usually closely associated with wolfram. The position of sphalerite with respect to pyrite and arsenopyrite cannot be directly observed, but that it is later is suggested by its relation to chalcopyrite and stannite. Sphalerite contains, in these specimens, innumerable minute almost sub-microscopic ex-solution droplets and veinlets of chalcopyrite and occasionally droplets of stannite; these minute inclusions are, of course, characteristic of sphalerite in many ore deposits. The droplets are sometimes discernible only with the highest magnification under oil immersion, and they have separated out from solid solution in sphalerite with lowering of the temperature. It is obvious that at high temperatures the sphalerite is capable of containing a number of other

molecules in solid solution. Quartz veins are commonly found in sphalerite (Pl. 9, fig. 1). In one specimen a vein containing bismuthinite was observed in it and in another bismuthinite slightly replaces sphalerite.

Stannite, besides occurring as ex-solution droplets in sphalerite, also forms occasional coarser grains. This coarser stannite may, like sphalerite, contain minute ex-solution droplets and also veinlets of chalcopyrite. For the most part stannite preceded galena (Pl. 9, fig. 2).

Chalcopyrite also occurs as coarser grains; it replaces and forms veins in arsenopyrite (Pl. 8, fig. 2) and pyrite and it also forms veins in galena (Pl. 10, fig. 2).

Bismuthinite sometimes occurs as coarse crystals, but usually it is associated with, and is veined along its cleavage, by galena; intergrowths are common (Pl. 9, fig. 4). The association of these two minerals suggests that they were deposited close together in time but that bismuthinite was the first to form. In one specimen bismuthinite accompanied calcite as a veinlet in sphalerite, but in other sections carbonate veins occur in bismuthinite. Apparent veinlets of bismuthinite are seen in quartz, and it occasionally replaces the latter (Pl. 9, fig. 3).

Galena was not found to vein sphalerite. It is, however, veined by chalcopyrite, the veinlets following the cubic cleavage in galena. Remembering the close association of chalcopyrite with sphalerite, this might, perhaps, suggest that galena was earlier than sphalerite, but as chalcopyrite separated from sphalerite only on the fall of temperature, it is probable that sphalerite (with some chalcopyrite and stannite in solid solution) was deposited at a higher temperature than galena. Galena and bismuthinite replace both pyrite and arsenopyrite.

Carbonate commenced deposition late in the sequence, as it veins all the preceding minerals. However, one case of a vein of chalcopyrite and galena in platy carbonate was seen. The carbonate is apparently a normal calcite, but where associated with chlorite it is a brown ferrous variety. Occasionally the gangue consists almost entirely of calcite with only a very little tourmaline or micaceous material. It has often replaced quartz in a remarkably thorough manner (Pl. 12, fig. 3).

Scheelite replaces wolfram (Pl. 6, fig. 4; Pl. 7, fig. 1; Pl. 12, fig. 1), and the resulting pseudomorph may retain both the form

and the cleavage of the prismatic wolfram. As a rule unreplaced relicts of the original wolfram prisms are retained. Scheelite which is interstitial is white, whereas that which has replaced wolfram is yellow, but the two are optically continuous and there is no reason to suspect that they are of different ages. Scheelite is commonly interstitial to pyrite and later minerals. It has been observed to replace quartz along the border of wolfram and is occasionally interstitial to quartz. Instances of its replacement by lepidolite and muscovite were noted. Scheelite was also seen to replace calcite along the latter's cleavage (Pl. 11, fig. 4), but the platy variety of calcite is commonly euhedral to it.

Muscovite (very fine-grained gilbertite) and lepidolite occur together; the latter is, perhaps, the earlier. Muscovite forms veins in cassiterite (Pl. 12, fig. 1) and also replaces and forms veins in wolfram, scheelite, tourmaline (Pl. 10, fig. 4), phenacite and the sulphides. Lepidolite occurs as small radiating groups and shows a typical colourless to pale pink pleochroism. Some of the muscovite is altered to a pale brownish variety. In one section veins of gilbertite in cassiterite stop abruptly at the border of scheelite after wolfram and continue on from the further side of the replaced wolfram, its position in the latter being occupied by a line of white scheelite (Pl. 12, fig. 1). This might suggest that the replacement of wolfram by scheelite was closely associated with the introduction of the micas.

Chlorite is sometimes seen to have been derived from muscovite, but much of it is truly hypogene. It may replace any of the earlier minerals. In one section a few thin veins of calcite were seen to vein chlorite.

Supergene changes.

Supergene changes in these minerals as a result of surface alteration are surprisingly few. Very small amounts of chalcocite, covellite, cerussite and tungstic oxide have been found at all horizons down to No. 4.

Distribution of the minerals.

Within the limits of the lodes from which specimens were obtained, there is no discernible arrangement of the minerals. From the specimens examined the minerals appear to occur independently

of any particular horizon and of the country rock, that is, of course, apart from the local minerals beryl, phenacite, orthoclase, garnet and zoisite.

Mr. Hobson has observed, however, that relative to wolfram, cassiterite definitely does increase in depth, and also that the sulphides increase in depth relative to the oxides; the same relation holds also laterally towards the more central part of the granite mass. Indeed, in the lower barren sections of the veins, sulphides occur to the exclusion of oxides.

PROCESS OF MINERALISATION.

Crystallisation and mineralisation within the magma.

Mineralisation at Mawchi has taken place in two ways—impregnation of cassiterite throughout the granite, and formation of the mineral veins. Both forms of mineralisation did not necessarily take place at the same time.

The granite is usually medium-grained, but is penetrated by both aplite and pegmatite dykes. It is apparent that, in granite, late magmatic or deuteric changes were widespread, and have arisen by the introduction mainly of H_2O and B_2O_3, with a certain amount of F and Li_2O; it may be presumed that the discrete cassiterite scattered throughout these granites was introduced at the same time that the deuteric reactions were taking place.

The granite is a massive rock through which, after crystallisation, both solutions and gases would have found it extremely difficult to penetrate, except along joint-planes or other fractures. Apart from local wall-rock alteration there does not appear to be any increase in deuteric change within the granite close to the veins. These changes are too widespread to have any relation to the veins, and there is no justification for attributing the post-magmatic changes in the granite to the same solutions as gave rise to the lode minerals.

The deuteric changes in the granite are apparently so evenly distributed that they immediately suggest a source within the body of the granite itself. The process of crystallisation of the granite from oligoclase through quartz and orthoclase and eventually to biotite, left a final liquid high in volatiles distributed in the remaining pore-spaces of the rock. This liquid consisted of H_2O, B_2O_3, F,

Sn, Li_2O, CaO, CO_2 and probably also a little quartz—the combinations in which these molecules may have occurred within the liquid need not concern us. So long as the total pressure of the surrounding rock exceeded the vapour pressure of this liquid at any particular temperature during cooling, these liquids would remain in contact with adjacent minerals, reacting with them, removing alkalies from the felspars and giving rise to tourmaline, muscovite, fluorite and calcite. The formation of joint-planes, *etc.*, on further cooling of the granite, would permit the ready dispersion of any liquid that may eventually have remained.

It is a curious fact that although disseminated SnO_2 is so widespread throughout these granitic rocks, wolfram has not been similarly detected. Wolfram does, however, occur in certain segregations which are commonly found in the granite. These segregations consist of cassiterite, wolfram (usually considerably replaced by scheelite), tourmaline and completely kaolinised felspars—one such segregation contained 22·6 per cent. Sn and 6·23 per cent. WO_3. Other segregations consist of tourmaline and quartz with a little cassiterite. These segregations may be regarded as of the nature of local pockets of final magmatic liquid, and in which sometimes WO_3 was concentrated along with the other constituents—its replacement by scheelite in these segregations is comparable with the relation between these minerals in the lodes and is presumably a matter of stability at lower temperature.

In view of the abundance of wolfram in the lodes, its apparent absence in the granite compared with cassiterite requires explanation. It is assumed that the Sn-bearing molecule in the magma would be much more volatile than the WO_3 molecule, in other words its vapour pressure is higher. Towards the end of crystallisation of the magma the greater part of the remaining liquid would be concentrated in the lower part of the magma reservoir but, with any tendency to pressure relief, the more volatile constituents would rise through the crystallising granite, in which there is sufficient liquid-filled pore-space to permit the ready movement of gases. Thus, the final liquid in the pore-spaces of the crystallised granite may acquire a certain proportion of Sn, whilst the less volatile WO_3 is relatively absent from them, although concentrated in the deep-seated residual liquid.

It is not supposed that these deuteric changes took place in the granite only after most of it had crystallised. As the magma

crystallised downwards and inwards from its roof and sides, these changes would be taking place in the crystallised rock. It is possible that some of the cassiterite in the upper granite had formed before the granite at greater depths had crystallised.

The formation of aplite and pegmatite dykes may have some connection with these changes. After a considerable proportion of the upper part of the magma had crystallised out, but whilst the remaining lower magma had not changed in composition to any considerable extent, apart from becoming somewhat more acid, relief to pressure along fissures in certain zones would permit this magma to rise into the overlying granite, and, with rapid loss of volatiles consequent upon this relief to pressure, such intruded magma could locally become "dry" and rapidly crystallise out as aplite. These aplites are usually rather less kaolinised than is the granite.

The pegmatites belong to a later phase than the aplites, and are more closely connected with the mineral veins themselves. They have been formed from a very late "wet" magma, in which crystallisation would be long-delayed, permitting a coarser-grained texture and the accompaniment of much muscovite. Local pockets of such magma may be left isolated in the consolidated rock and may eventually give rise to pegmatites in the granite; such pegmatites need have no roots and even small tin veins may be formed in this way. Other pegmatites may be derived from magma which has come from depth. It is probable that some of the constituents (such as felspar and quartz) of these pegmatites were picked up by the liquid in consequence of its reaction on the granite during migration or the liquid may actually recrystallise the granite *in situ*. There is a gradation between some pegmatites and the quartz lodes proper.

Finally the stage of formation of the mineral veins was reached. There appear to be all stages between the pegmatites and lode quartz, even within some of the veins themselves. Hence the veins must be regarded as representing a final phase immediately following and, in fact, a continuation of the pegmatite intrusions. The residual liquid was obviously extremely high in volatiles and its vapour pressure must have increased enormously in the final stages. Once fissures in the overlying granite tapped this liquid its injection must have been almost instantaneous. The extreme pressure of these liquids would assist in widening the vein walls, even apart from any replacement which may have taken place.

The vein liquid.

Following injection, with sudden relief to pressure, the more volatile constituents would tend to escape and react with adjacent minerals of the wall-rock or find their way towards the surface and would thus be entirely lost to the remaining ore liquid. It is noticeable how completely the fluorite and much of the tourmaline was deposited at the beginning of the sequence. It is possible that a considerable part of the H_2O content of the ore liquid also was dispersed after injection. The remaining liquid still contained some B_2O_3 and was obviously high in silica, tin, wolfram, iron, manganese, sulphides, calcium, with also a little beryllium, alumina, magnesia, lithia and alkalies,—a liquid which must obviously be alkaline in reaction. The mode of combination of the Sn was certainly not as a fluoride, for all F had now disappeared; it was presumably in the form of SnO_2. The stability of such a liquid cannot be reconciled with a normal solution in which H_2O is the dominant constituent. It may be suggested that, following on the sudden change in composition of this ore liquid after injection and loss of volatiles, the constituents separated out as a dispersed colloid. The prolonged and gradual crystallisation from this colloid eventually gave rise to very coarsely crystalline vein minerals; the early sequence of tourmaline, cassiterite, wolfram, beryl and quartz being followed by sulphides and carbonates. There is no evidence and no justification for the assumption that, in these veins, the ore liquid was in constant upward movement, and, apart from loss of water in an upward direction along the lode channel itself as the colloid crystallised, there could have been no great redistribution of material. Shrinkage accompanying crystallisation of the colloid, with adjustments along the lode under pressure, would give rise to sufficient mineral fracturing to permit movement of this final water. The last minerals to form, carbonates and scheelite, were probably the results of the reactions of this residual water.

In the above picture it has been suggested that the ore liquid was injected as a liquid. There is the possibility that, with relief to pressure, the residual magmatic liquid as a whole was injected as a vapour phase which condensed to a liquid in the higher and cooler parts of the granite before deposition, or deposition may even have taken place direct from the vapour phase. Such a process would give rise to a more marked differentiation than is noticeable in these lode minerals, in which volatile and relatively non-volatile

constituents are closely associated. Apart from the earliest minerals in the ore sequence, fluorite and tourmaline, which may have been formed as the result of the reaction by F and B_2O_3 vapour given off directly from the injected ore liquid, the rest of the lode materials examined appear to have been deposited from an ore liquid which had not passed through a vapour phase.

Conclusion.

One point which I have endeavoured to bring out is that in these magmas, which contain an abundance of highly volatile constituents, there is not, during crystallisation, one single stage which can be referred to as pneumatolytic. The action of these volatile constituents both as vapours and in the liquid phase is continuous right from the moment of intrusion to the final stage of ore deposition. Loss of volatiles, whether it be by mere vaporisation or consequent upon phases of ebullition, is a continuous process.

The activity of a vapour phase is, however, relatively unimportant. The main function of the volatiles is the prolonged retention of a liquid phase down to a very low temperature, permitting a long-continued reaction of this liquid with the minerals throughout the body of the rock, and thus giving rise to widespread deuteric changes. These changes take place right from the commencement of crystallisation of any part of the magma. Kaolinisation is a continuous process from early crystallisation of felspars in such magma. In the deep-seated residual magma the volatiles were responsible for the extremely high vapour pressure which ultimately caused injection of the liquid into the overlying granite.

It is doubtful whether the ore liquids, as a whole, were the product of condensation from a vapour phase. They always were a liquid, although volatiles passed off as vapour at any stage that the rock pressure permitted, and reacted either with the wall rock or continued to the surface. With loss of volatiles the "solid" constituents of the ore liquid possibly separated into a dispersed colloid from which crystallisation finally took place.

The earlier cassiterite in the granite may have been precipitated from SnF_4, but in the ore liquid at least it was in the form of SnO_2, presumably as a dispersed colloid.

DISCUSSION.

On reading this manuscript Mr. G. V. Hobson made two apposite observations. Concerning the relationship between cassiterite and wolfram he remarks:

"From field evidence one is bound to accept the very close relationship between cassiterite and wolfram as regards their period of deposition. If, however, wolfram preceded cassiterite one might expect that as one progressed outwards from the granite, or from zones of higher temperature to zones of lower temperature there should be a fall in the ratio of wolfram to tin. Actually the reverse appears to be the case. I have made no calculations on this point, but taking the mine as a whole I think I am right in saying that, with increasing depth, the tin has risen very considerably in relation to wolfram."

He makes a similar observation concerning arsenopyrite and pyrite:

"Here again the lower temperature character of the arsenopyrite and pyrite would lead one to expect them in greater profusion in the outer zones of the deposit. The reverse is the case; as development progressed inwards towards the more central part of the granite, both vertically and laterally, sulphides became more prevalent. In the lower barren sections of veins sulphides (all of them) occur and oxides do not."

However, Mr. Hobson supplies the partial answer himself by suggesting that

"All these anomalies may be due to extreme rapidity of formation, so that relative concentration rather than relative temperature of formation, was the controlling factor."

In addition, I would emphasise again what has been said in discussing the vein liquid. The injection of these liquids was sudden and deposition was not from a moving liquid as is pictured in most mineral veins which show zoning. Deposition was first determined by relief to pressure and secondly to temperature. Under such conditions the lower temperature minerals may be expected to occur rather more abundantly in the lower parts of the veins where deposition was prolonged a little. Only considerable re-opening of the veins during deposition could have permitted movement of the ore-liquid and zoning of the lower temperature minerals in the upper levels—and such movement was absent or negligible in these veins. The relationship which Mr. Hobson points out is, therefore, not unexpected.

EXPLANATION OF PLATES.

PLATE 6, FIG. 1.—Cassiterite (C) interstitial to wolfram (W). Quartz (Q). P. S. 252. × 54.

FIG. 2.—Cassiterite (C) and molybdenite (M) interstitial to wolfram (W). Bakelite (B). P. S. 251. Crossed nicols. × 54.

FIG. 3.—Wolfram (W) partly enclosing a tourmaline crystal (T) in quartz (Q). P. S. 243. × 54.

FIG. 4.—Scheelite (dark grey), replacing wolfram (light grey). P. S. 231. × 54.

PLATE 7, FIG. 1.—Wolfram (W) crystal replaced by scheelite (S). Cassiterite (C) and quartz (Q). Bakelite (B). P. S. 251. × 28.

FIG. 2.—Quartz (Q) replacing wolfram (W). A little pyrite (P). P. S. 236. × 54.

FIG. 3.—Pyrite (white) veinlets in quartz (Q) and wolfram (W). P. S. 232. × 54.

FIG. 4.—Pyrite (P) veining tourmaline (T), and both replaced and veined by chlorite (C). P. S. 239 B. × 54.

PLATE 8, FIG. 1.—Pyrite (P) and chalcopyrite (C), veining arsenopyrite (A). Quartz (Q). P. S. 164. × 28.

FIG. 2.—Arsenopyrite (white) veined by chalcopyrite (grey) and carbonate (black). P. S. 164. × 180.

FIG. 3.—Arsenopyrite needles in chlorite (dark grey); the latter replaces quartz (lighter grey) and galena (white). Pyrite (P). P. S. 236. × 54.

FIG. 4.—Sphalerite (S) veining and replacing arsenopyrite (A). Also chalcopyrite (C) and carbonate (Ca). P. S. 242. × 84.

PLATE 9, FIG. 1.—Quartz veins in sphalerite. P. S. 173. × 40.

FIG. 2.—Stannite (S) and galena (G) which veined stannite but is altered in part to cerussite (Ce). Wolfram (W). P. S. 166. Oil immersion. × 420.

FIG. 3.—Molybdenite flake (M) in bismuthinite (B) and quartz (Q), the bismuthinite replacing the quartz along the molybdenite. Note the strong difference in reflectivity between adjacent areas of bismuthinite. P. S. 175. × 54.

FIG. 4.—Intergrowth of bismuthinite in galena. Crossed nicols. P. S. 235. × 54.

PLATE 10, FIG. 1.—Galena vein (white) in cassiterite (C). Quartz (Q). P. S. 235. × 180.

FIG. 2.—Chalcopyrite (C), partly altered to chalcocite and covellite, and stannite (S) vein along cleavage in galena. P. S. 166. × 235.

FIG. 3.—Zoning in cassiterite (thin section). Mic. slide 24690. × 24.

FIG 4.—Tourmaline (T) replaced by muscovite (M) and chlorite (Ch) in cassiterite (C) and wolfram (W). Mic. slide 24681. × 24.

PLATE 11, FIG. 1.—Cassiterite replaced by interstitial felspar. Mic. slide 24680. × 24.

FIG. 2.—Cassiterite replaced and veined by beryl. Mic. slide 24687. × 24.

FIG. 3.—Beryl replaced along its cleavage, at walls of scheelite vein. Mic. slide 24685. × 24.

FIG. 4.—Scheelite replacing platy carbonate. Mic. slide 24683. × 24.

PLATE 12, FIG. 1.—Mica veins (M) in cassiterite (C). Note how one of them stops at the border of scheelite (S) after wolfram, and its position in the latter occupied by clear scheelite. Tourmaline (T). Mic. slide 24688. × 24.

FIG. 2.—Tourmaline (T) and cassiterite (C) veined by lepidolite (M). Mic. slide 24698. × 24.

FIG. 3.—Relict quartz in platy carbonate. Mic. slide 24690. × 24.

FIG. 4.—Platy carbonate. Mic. slide 24696. × 24.

TIN-TUNGSTEN MINERALISATION AT HERMYINGYI, TAVOY DISTRICT, BURMA. BY J. A. DUNN, D.Sc. (MELB.), D.I.C. (LONDON), F.N.I., F.G.S., *Petrologist, Geological Survey of India.* (With Plates 13 and 14.)

CONTENTS.

INTRODUCTION.

At the instigation of Mr. E. L. G. Clegg, Superintending Geologist of the Burma Geological Department, Geological Survey of India, Mr. Jackson, Manager of the Hermyingyi mine, Tavoy, Burma, sent to me selected specimens of the mine ore for examination under the ore-microscope. The Hermyingyi specimens were of interest from the point of view of comparison with the Mawchi ores in Karenni which had been previously studied.

Only eighteen specimens were sent, and all of lode material, so that the study cannot be regarded in any sense as exhaustive. In comparing them with the Mawchi ores, the greater coarseness and simplicity of the mineral development of the Hermyingyi lodes becomes at once apparent. This could, of course, be merely an incidental feature of the specimens submitted, but almost any specimen from Mawchi would show a diversity in mineral assemblage greater than the whole of this set of Hermyingyi ores, and no Mawchi specimen examined by me has such coarse crystals as those from Hermyingyi.

GEOLOGY.

The geology of Tavoy has been described in detail in a memoir by Drs. J. C. Brown and A. M. Heron.[1] In this memoir a full bibliography is provided of the geological work which had been undertaken in this part of Burma prior to 1923.

Briefly, the rocks consist of a presumably pre-Cambrian group of sediments, the Mergui series, intruded by granite. The Mergui series comprises argillites, volcanic agglomerates, quartzites, occasional limestones and conglomerates, which strike N.N.W.-S.S.E. and dip at a high angle from 60 degrees to vertical.

At Hermyingyi about sixty different veins had been worked. In general they strike N.N.E.-S.S.W. and have an easterly dip. They have been followed for a distance of 500 to 1,100 feet and have a width of 10 inches to 5 feet. The veins continue upwards from the granite into the sedimentary rocks above. The proportion of WO_3 to SnO_2 in the concentrates from the veins was approximately 2 to 1.

The veins usually have well definedwalls with often a thin selvage of mica, and, almost throughout, narrow bands of the wall-rock in granite country have been altered to a quartz-mica greisen which sometimes contains sufficient cassiterite and wolfram to be profitably mined.

VEIN MINERALS.

The ore minerals in the specimens examined consist of wolfram, cassiterite, pyrite, sphalerite, chalcopyrite, galena, bismuthinite, molybdenite, and native bismuth in that order of abundance. The gangue minerals include quartz, muscovite and fluorite. In addition, Brown and Heron record the presence of topaz along the wall of one vein. Supergene minerals include WO_3 ochre, covellite and a little limonite.

Four minerals, present in the Mawchi ores, are absent from the Hermyingyi specimens: scheelite, arsenopyrite, tourmaline and calcite. This cannot be entirely incidental to the specimens examined because there is scarcely a specimen from Mawchi in which at least scheelite and tourmaline are not abundant. Brown and Heron have remarked on the absence of tourmaline from the wolfram veins in Tavoy. They do, however, record the occasional presence

[1] J. C. Brown and A. M. Heron, The Geology and Ore Deposits of the Tavoy District, *Mem. Geol. Surv. Ind.*, XLIV, Pt. 2, 1923.

of scheelite, and even more rarely of arsenopyrite and calcite. The abundance of these minerals in the Mawchi ores provides a strong contrast. Fluorite is rather more abundant in the Hermyingyi ores than at Mawchi.

The microscopic characters of these minerals have already been described, so that there is no necessity to repeat them here.

Ore minerals.

Wolfram.—This is almost invariably in coarse and thin bladed crystals, up to 6 inches in length, with excellently developed cleavage, and often very friable. Against quartz it commonly shows crystal faces. A film of WO_3 ochre, of a white or pale yellow colour, is very often found along the cleavage.

An analysis of carefully picked material gave the following results :—

WO_3	75·20
FeO	8·48
MnO	15·26
MgO	0·05
CaO	0·05
SnO_2	0·24
SiO_2	0·18
Al_2O_3	0·89
	100·35

Analyst—Mahadeo Ram

This, then, is a wolfram in which the Mn : Fe ratio is 2 : 1. It may be compared with the wolfram from Mawchi in which the Mn : Fe ratio is approximately 3 : 2.

Cassiterite.—This is often in coarse crystals over one inch diameter. A characteristic of the Hermyingyi cassiterite is its rather pale brownish colour as compared with the more usual deep brown to black colour elsewhere. The cleavage is well developed and the mineral is often extremely friable, especially where there has been slight crushing. Zoning is not particularly common in the Hermyingyi mineral.

Pyrite.—Where present, this mineral usually shows a euhedral outline against quartz, and commonly occurs in perfectly developed little cubes, but against other minerals it is much more irregular.

Sphalerite.—The characteristic ex-solution droplets of chalcopyrite are more beautifully developed in the Hermyingyi sphalerite than perhaps in any other specimens which I have previously seen. Sphalerite is not particularly abundant and occurs only in occasional specimens.

Chalcopyrite.—Wherever sphalerite occurs, there, also, chalcopyrite is invariably found. Besides forming ex-solution droplets in sphalerite, small patches replace and vein other minerals.

Galena.—Small patches and veins of galena are occasionally seen but are not particularly abundant, and are usually minute.

Bismuthinite.—Fine-grained granular bismuthinite is usually associated with galena and is found as rare veinlets in other minerals. The two are not readily distinguishable under reflected light although the reflection pleochroism of bismuthinite can be observed; however, with crossed nicols the pronounced anisotropic colours of bismuthinite are characteristic.

Bismuth.—Ex-solution droplets of native bismuth were seen in some of the bismuthinite (Plate 14, fig. 4). The mineral is very rare and no large patches were seen. It is readily diagnosed because of its extreme softness, high reflectivity and characteristic colour. It is so soft that it flows during polishing.

Molybdenite.—A few flakes of molybdenite may be seen in quartz, but its more usual mode of occurrence is as aggregates of fine-grained flakes either in quartz or interstitial to wolfram.

Gangue Minerals.

Quartz.—Coarse white quartz is the main gangue mineral. Occasionally the quartz shows crystal faces in the centre of the veins, where the interfaces may be filled in with muscovite.

Muscovite.—Usually the muscovite occurs in small silvery flakes or pale greenish aggregates. It occurs on the vein walls, often as a thin selvage, or as thin lines in quartz parallel to the vein walls and giving to the veins a somewhat banded appearance. Commonly, also, it is interstitial to wolfram and to quartz, in which case the flakes are often distorted. Sometimes a very fine, almost earthy, white sericitic mica veins the wolfram.

Fluorite.—Although by no means abundant, a little fluorite is seen in the majority of specimens. It is pale yellowish, or pale greenish in colour. It is usually interstitial to wolfram and muscovite and is commonly associated with the latter.

Supergene Minerals.

Tungstite.—WO_3 ochre occurs as a fine-grained powder which veins wolfram and other minerals and occasionally replaces patches of wolfram. Under the reflecting microscope it is readily distinguished by its softness, a reflectivity which is just lower than wolfram, and its pale yellow to white inner reflection.

Covellite.—This occurs as thin veinlets in any of the hypogene minerals, and it occasionally directly replaces chalcopyrite.

"*Limonite*".—A little limonite is developed where the veins have been leached and are rather cellular, particularly on the vein walls. Wolfram has occasionally altered partly to limonite.

THE ORES.

The veins show a consistent structural relation between the minerals: wolfram and cassiterite form more particularly along the walls and quartz predominates in the centre of the veins. The coarse bladed wolfram grew outwards from the vein walls, extending into the quartz towards the centre of the veins. Wolfram, in these specimens, is much more abundant than cassiterite. Green and silvery muscovite is commonly found as a thin selvage along the vein walls, but in addition it occurs interstitially to the wolfram and as thin lines in the quartz, sometimes giving to the veins a banded appearance.

The position of muscovite in the sequence is by no means definite. In only one case was it found to be veined by wolfram (Pl. 13, fig. 1) and no other mineral replaces it. Yet it appears to be interstitial to wolfram, although on close examination such muscovite is usually bent, as if pushed aside by the wolfram. It is often closely associated with fluorite. Its consistent position on the vein walls suggests that muscovite was the earliest mineral, but some of it does undoubtedly vein quartz. The assumption follows that there were two periods of deposition of muscovite. A very fine white sericitic mica sometimes veins wolfram.

On the whole, cassiterite appears to be interstitial to wolfram and tends to crystallise after the latter, but an unusual example of cassiterite grains replaced by wolfram was observed in one specimen (Pl. 13, fig. 3). As in the Mawchi ores, crystallisation of these two minerals obviously overlapped.

Flakes of molybdenite in quartz are apparently earlier than the latter and the little evidence available would suggest that the molybdenite is later than wolfram. Its position with respect to pyrite is uncertain.

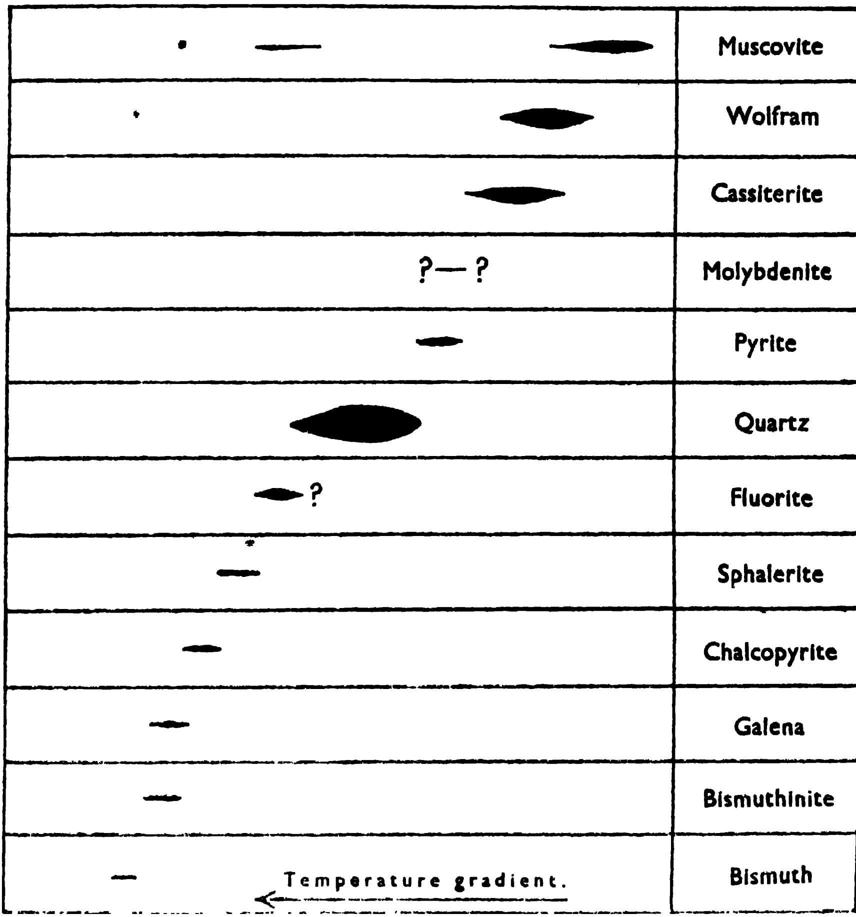

FIG. 1.—Mineralisation sequence of Hermyingyi.

Pyrite is clearly later than wolfram and cassiterite, but its position with respect to quartz is not quite clear. In most cases it shows euhedral outlines against quartz, and, when the pyrite and quartz occupy sections of the same veinlet in wolfram, the pyrite

usually shows a crystal outline against the quartz section of the veinlet. Some pyrite is, however, replaced by quartz. In general, then, pyrite was earlier than quartz.

Examples of quartz veining or replacing cassiterite are rare (Pl. 13, fig. 4), but quartz quite commonly replaces and veins wolfram. It is noticeable in several specimens that prior to deposition of quartz the wolfram was crushed and fractured and sometimes finely brecciated (Pl. 13, fig. 2).

In the majority of specimens the position in the sequence of fluorite is not clear, but in one or two specimens it definitely replaces quartz (Pl. 14, fig. 1). The commencement of fluorite deposition remains unknown, but it certainly continued after quartz. This is in contrast to the Mawchi ores, in which fluorite was determined to be amongst the earliest minerals deposited, but its lower limits there were uncertain. Veins of galena and bismuthinite have been seen in the Hermyingyi fluorite.

Sphalerite replaces pyrite and quartz. Chalcopyrite separated from sphalerite on further cooling and in addition small patches of chalcopyrite replaced and veined sphalerite (Pl. 14, fig. 2). Galena veins penetrated sphalerite and in addition galena replaces chalcopyrite. Bismuthinite is closely associated with the galena, and bismuth obviously separated from the bismuthinite with lowering of the temperature. Veins of galena and bismuthinite in wolfram are common (Pl. 14, fig. 3).

SUPERGENE CHANGES.

Alteration of wolfram to tungstite and of chalcopyrite to covellite is found throughout these ores, and at depths of 314 feet from the surface. The leached appearance of some of the ore indicates the activity of surface waters at all depths.

THE ORE LIQUID.

The emplacement of these ores in the veins would appear to have been a simple injection of the ore liquid along the vein fissures. The elongated habit of the wolfram, many of the slender crystals projecting from the walls into the coarse quartz towards the centre, at once indicates that there could not have been any important

reopening of the fissures prior to deposition of later minerals; whatever crushing of wolfram that did take place was local and probably due to small adjustments during crystallisation. The whole aspect of these coarsely crystalline veins is that of a siliceous ore liquid suddenly injected, probably under pressure such as to force the walls apart, and slowly crystallising from the walls inwards.

There is no evidence leading to the assumption that the Sn was injected other than as oxide or the tungsten other than as the wolfram molecule. Fluorite is present in only very small amounts although it is more abundant than in the Mawchi ores, and, apart from prolonging crystallisation to a rather lower temperature, fluorine was a relatively unimportant agent in the ore liquid. The total absence of B_2O_3 is remarkable for ores of this nature, and there is not a characteristically high temperature mineral in the sequence. The ores were deposited at very low temperatures from a liquid which was apparently not acidic, and it is not unlikely that the final state of the ore liquid prior to crystallisation was that of a colloid.

The comparison with the Mawchi ores may be completed, then, with the observation that the Mawchi ores crystallised within a rather wider range of temperature, the earlier minerals being characteristically high temperature minerals, and the later separating at a much lower temperature. The Hermyingyi ores commenced crystallisation at quite a low temperature, probably in consequence of the rather higher amount of fluorite present. At Mawchi, fluorine escaped from the ore liquid at an early stage, at Hermyingyi it was fixed in the fluorite molecule, calcium carbonate being absent. The absence of calcium carbonate is also the explanation of the absence of scheelite from these ores, the wolfram, apparently unstable in the presence of calcium carbonate, remaining unreplaced.

The quartz-mica-greisen which is so common along the walls of these veins was probably formed by the residual waters, unable to escape fully along the lode channels, soaking into the walls and replacing the felspars by muscovite. It is illogical to presume that this greisen provides evidence of the very dilute nature of the ore liquid, for the greisen bands are relatively narrow and the amount of water which they represent is relatively small. In my opinion there is no evidence which would suggest that the ore liquids were of such a dilute nature as is usually pictured; deposition from a by no means highly dispersed colloid is a possibility that is in conformity with the little evidence which this study has afforded.

EXPLANATION OF PLATES.

PLATE 13, FIG. 1.—Wolfram veining muscovite (M) which appears also to be interstitial to coarser wolfram (W). Quartz (Q). P. S. 268. × 54.

FIG. 2.—Wolfram (light grey) brecciated and veined by quartz (dark grey). P. S. 268. × 54.

FIG. 3.—Cassiterite (dark grey) replaced by wolfram (grey). Quartz vein to left. P. S. 266. × 54.

FIG. 4.—Cassiterite (white) veined and replaced by quartz (grey). P. S. 265. × 54.

PLATE 14, FIG. 1.—Fluorite (F) replacing quartz (Q). Wolfram (W) and tungstite (T). Cracks in fluorite, infilled with bakelite, appear like quartz. P. S. 267. × 54.

FIG. 2.—Pyrite (P) replaced by sphalerite (S), in turn veined by chalcopyrite (C) and galena (G). P. S. 278. × 54.

FIG. 3.—Veins of galena and bismuthinite (white) in wolfram. P. S. 267. × 54.

FIG. 4.—Ex-solution droplets of bismuth in bismuthinite. P. S. 277. Oil immersion. × 540.

TWO FOSSIL DICOTYLEDONOUS WOODS FROM THE GARO HILLS, ASSAM. BY K. AHMAD CHOWDHURY, *Forest Research Institute, Dehra Dun.* (With Plates 15 and 16.)

CONTENTS.

INTRODUCTION.

The material on which the present study is based was collected by Dr. C. S. Fox of the Geological Survey of India in January, 1933. Two years later he kindly handed it over to the writer for investigation. The material consisted of two specimens, both collected in the Garo Hills district, Assam. The specimen G. S. I. Type No. 16502 was from Damalgiri, about eleven miles west of Tura, headquarters of the district. In size it was about 8 cm. long, 4 cm. broad and 2 cm. thick. G. S. I. No. K40/485 was from a place about a mile north-west of Garobadha, nineteen miles west of Tura. It was a smaller specimen than G. S. I. Type No. 16502, about 4 cm. long, 3 cm. broad and 2 cm. thick. The preservation of both the

specimens was far from satisfactory for a complete anatomical study, although G. S. I. Type No. 16502 was somewhat better than G. S. I. No. K40/485. Slides prepared from G. S. I. Type No. 16502 showed sufficient anatomical structure to ensure its identification, while those from G. S. I. No. K40/485 were far too brittle to be ground to the required thinness. In this connection it is interesting to note that microscopic examination of G. S. I. Type No. 16502 revealed fungal hyphæ in its woody tissues (Pl. 16, fig. 2), but not in G. S. I. No. K40/485.

Geologically the locality is known to be Tertiary but no definite information is at present available as to the exact age of the fossil bed. In the recent geological map it is coloured as Siwalik, which is equivalent to the Tipam stage of the Assam series. Occurrences of fossils in this particular area have already been reported. Pinfold (28) found some fossils at about 4¼ miles distance from Dalu, on the road from Dalu to Tura, and also at about a mile from Bagmara, on the foot-path from Bagmara to Dalu. Based on palæontological information alone he was not inclined at that time "to correlate succession of Garo Hills with that of Assam." Vredenburg (38) carefully studied Pinfold's specimens and made some interesting observations. He compared these fossils with those from north-western India, Burma and Java, and provisionally placed them along with the Upper Gaj of Sind and the Pyalo beds of Burma. He was of opinion that further investigation would be necessary before coming to a final conclusion. Later on Evans (12) and his co-workers reported additional fossil localities near Dalu and Bagmara. These workers were of opinion that the fossil-bearing beds could be regarded approximately as Upper Gaj or Burdigalian. Further information on this question will perhaps be available when Dr. Fox, who has been engaged for some time on the geological survey of this part of Assam, completes his work.

(A) SPECIMEN G. S. I. Type No. 16502.

(1) Anatomical description.

Growth rings.—The cross sections did not show any growth marks either to the naked eye or with a hand lens (Pl. 15, fig. 1), nor did careful search under a high power microscope reveal any structural difference indicating boundary of the growth ring (Pl. 15, figs. 2 and 3). However, at one extreme corner of the fossil, some suggestion

of growth marks was noticed, which under a high power microscope turned out to be nothing but a group of gum ducts aligned tangentially.

Vessels.—Distribution of the vessels is more or less uniform throughout the wood, without any tendency to grouping at any particular place (Pl. 15, figs. 1, 2, 3). Individual vessels or vessel groups are distinctly visible to the eye, appearing as dots against the ground tissue of the wood. This timber also shows some comparatively small vessels, which are distributed rather sporadically (Pl. 15, fig. 2). At first it was thought that these might be solitary gum ducts, but careful examination revealed their tracheal nature. For the most part the vessels are medium-sized and they are either solitary, or in radial or obliquely radial groups of 2 to 4. In transverse sections the tyloses are not very distinctly visible but in longitudinal sections their presence cannot be overlooked (Pl. 15, fig. 6). Vessel cavities are often plugged with a darkish deposit of a gummy nature. Vessel lines are often prominent on the longitudinal surfaces, due to the coloured deposit that they contain. Perforation plates are simple, horizontal to slightly inclined. Inter-vessel pit pairs are fairly large, alternate; outlines of the border are oval and widest horizontally; the aperture is lenticular and horizontal or slightly oblique (Text-figs. 1, 2). Vessel-tracheid pits are similar to those of the inter-vessel. Vessel-ray pits are distinctly of two types and show some similarity to inter-vessel pits. They are one to several per ray cell; when one, usually large (Text-fig. 3); when several, they are comparatively small. The outline of the border is round to oval. The aperture is oval to lenticular, horizontal or slightly oblique. Vessel-parenchyma pits are of the same type as those of vessel-ray but in this case the large type is less common than the small type.

Tracheids.—Although they are not distinguishable under low power, careful examination of some vessels under a high power microscope shows their vasicentric distribution, often intercepted by parenchyma cells. They are mostly flattened to conform to the wall of the vessel and are usually in a single row. As regards pits, they are of the same type as those found on the wall of the vessel, their size and shape depending on the cells that are contiguous to them.

Wood fibres.—Outline of the fibres can only be distinguished under high magnification. As a rule, they are irregularly arranged,

although they may show somewhat radial alignment in small patches (Pl. 15, figs. 1, 2). The thickness of the fibre wall varies from thick

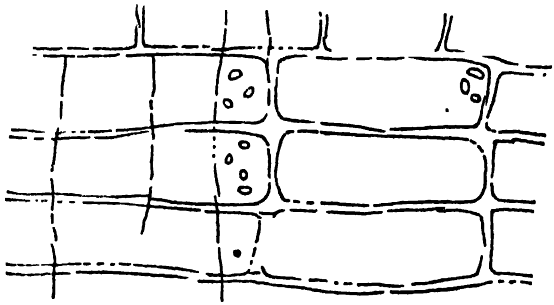

Fig. 1 (X 340)

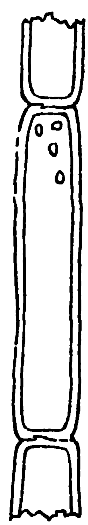

Fig. 2 (X 340)

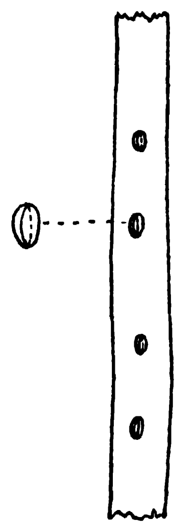

Fig. 3 (X 600)

FIGS. 1-3. *Dipterocarpoxylon garoense* sp. nov. (Semi-diagrammatic camera-lucida drawings).

FIG. 1. Showing pits between wood rays and longitudinal parenchyma cells; note grouping of pits. Fig. 2. Portion of longitudinal parenchyma cells showing inter-parenchyma pits. Fig. 3. Portion of a wood fibre with pits.

to very thick. Longitudinal sections do not give the correct impression of fibre wall thickness, which can best be gauged either in transverse sections or in macerated material. No septate fibre has been

observed, although occasionally some fibres show resinous contents. Inter-fibre pits are simple or bordered; the outline is round to oval; the aperture is slit-like, vertical or slightly oblique (Text-fig. 3).

Parenchyma.—The amount of parenchyma present is scanty to fairly abundant. Paratracheal parenchyma cells are in a sheath of 1 to 3 (mostly 2) cells often intercepted by tracheids (Pl. 15, figs. 1, 2 and 3). Metatracheal parenchyma cells are in narrow to wide bands. They are irregularly spaced and mostly discontinuous (Pl. 15, figs. 1, 2). When surrounding the gum ducts they are usually in a row of 3 to 6 cells. Diffuse parenchyma cells are also present but are rather scanty. Inter-parenchyma pits are round to oval. They are of two types; the small type is in clusters (Text-fig. 2) while the large type is usually single. Parenchyma-ray pits are similar to those of the inter-parenchyma (Text-fig. 1).

Rays.—On the cross surface of the fossil the rays are visible to the eye and under a hand lens (× 10) their outlines are fairly distinct. They are more or less uniformly distributed, moderately numerous and moderately broad (Pl. 15, figs. 1, 2, 3). On the radial surface of the fossil they do not show up conspicuously. Of the slides cut in three different planes the tangentials have given the best view of the diagnostic characters of the rays. They are mostly heterogeneous and can be classified more or less into three groups (Pl. 15, fig. 5). (1) The uniseriate type is composed of upright cells only. As a rule this type is not very high. (2) The biseriate type is also fairly common, and it shows only a few procumbent cells at the middle portion of the ray, the rest being composed of upright cells. (3) The majority of the rays are 5 to 8 (mostly 5 to 6) seriate. A row of upright cells forms the outer boundary of the rays and the inner portion consists of procumbent cells packed in an irregular fashion. The pits between ray cells are numerous. Their outlines are not so distinct in tangential sections but from some partially macerated material it has been possible to notice that they are small, oval or nearly so. As a rule, the rays are very low to low, but when vertically fused they run to a considerable height.

Gum ducts.—A casual observation of the cross sections might give an impression of a large number of vertical gum ducts, but careful microscopic examination proves it to be incorrect. Some thin-walled vessels with resinous contents do show up somewhat like the gum ducts, but the tracheal origin of their surrounding cells can be easily detected. The gum ducts show a few layers of

surrounding parenchyma cells which are often arranged in radial rows (Pl. 15, fig. 4), while the vessels containing gummy deposit have at least a few tracheids round about them (Pl. 15, fig. 3). By this method it has been possible to detect some vertical gum ducts in this fossil and these are classified under two groups: (1) diffuse or scattered in groups of 1 to 3 and (2) in a long row of tangential bands (Pl. 15, figs. 1, 2). But no horizontal gum ducts have been observed in the fossil.

(2) Comparison with living dicotyledons.

In the description of the fossil given above, the presence of vertical gum ducts has been recorded. This is of great importance from an anatomical point of view, for according to Solereder (37) and Record (30) only four orders are known to possess the gum ducts of the normal type found in the fossil. They are *Cornaceae*, *Simarubaceae*, *Leguminosae* and *Dipterocarpaceae*. In *Cornaceae* the genus *Mastixia* (30) is said to have vertical gum ducts, but the timber specimens of this genus in the Dehra Dun collection did not reveal any gum duct. Moreover, the woods of *Mastixia* show very little similarity with this fossil either in general structure or in minute anatomy. In *Simarubaceae*, only one genus *Simaruba* (30), which is mostly confined to tropical America, has this special feature. Besides the gum ducts there is very little similarity between *Simaruba* and this fossil. In *Simaruba* the distribution and the shapes of both ray and parenchyma cells are entirely different from those of the fossil. There appears to be, therefore, no justification for imputing any affinity of the fossil G. S. I. Type No. 16502 with the genus *Simaruba*. Then comes the sub-order *Caesalpinieae* of the *Leguminosae* in which the genera *Copaifera*, *Daniella*, *Eperua*, *Kingiodendron*, *Prioria* and *Sindora* have normal vertical gum ducts. Now, taking them one by one, in a *Copaifera* of tropical America, Record and Mell (29) reported vertical intercellular canals, but Chalk and his co-workers (3) did not find any canals in two African species that they had studied. Apart from the gum ducts, the general features of the *Copaiferas* are entirely different from what has been found in the fossil; for instance, the *Copaiferas* show distinct growth rings and have vasicentric and confluent parenchyma, and their rays are exclusively homogeneous. In view of these differences there does not appear to be any affinity between this fossil and the *Copaiferas*. Next comes *Daniella*, a genus growing in tropical

Africa. It has been possible to examine only one species of this genus. This shows paratracheal parenchyma, often forming conspicuous 'eyelets' and distinct ripple-marks. In view of these anatomical differences, its affinity to the fossil does not seem to be possible. The next genus, *Eperua* of Brazil and the Guianas, was not available for comparison. However, Record and Mell (29) report on *Eperua falcata* as having distinct growth rings while Bancroft (1, 2) reports the presence of ripple-marks in it. By these two features alone, the affinity of the fossil to this genus does not seem to be justified. *Prioria copaifera* Record and Mell (29) describe as having parenchyma vasicentric and "numerous irregularly spaced tangential and concentric lines". Thus it will be seen that none of the Caesalpinioid woods with normal vertical gum ducts can be profitably compared with the fossil under investigation.

Dipterocarpaceae is the only order which now remains to be critically examined. Except *Monotes* and *Marquesia* (2) all its genera are known to have vertical gum ducts in their woods. The diagnostic anatomical features of this order are vertical gum ducts, tracheids adjacent to the vessels, vasicentric parenchyma in thin intercepted bands, metatracheal parenchyma in short or long rows at unequal distance and heterogeneous rays. It will be seen that the fossil under investigation shows all these features in common with the wood of the *Dipterocarpaceae*. Moreover, the type of pitting found on the different kinds of cells in Dipterocarpaceous wood are also the same as has been recorded for the fossil. In view of these facts it would appear that the fossil G. S. I. Type No. 16502 belongs to the order *Dipterocarpaceae.*

The wood of the *Dipterocarpaceae,* on account of their commercial importance, have been studied to some extent by various plant anatomists (14, 25, 24, 32, 26, 13, 10). Most of these publications are confined to the woods of different political or geographical regions. Complete anatomical data of various genera and species growing in different countries are not available at present. It is not, therefore, possible to trace the fossil to any particular species. In this connection it may, however, be mentioned here that some seven years back a start was made in this laboratory to collect anatomical data of the various Dipterocarpaceous woods obtained both from India and abroad. This work is not yet complete, but based on the available data, the following tentative classification is suggested. Leaving aside *Monotes* and *Marquesia,* the rest of the

family can be divided into two main groups. Those which have gum ducts mostly in concentric bands extending over an inch will come under one group. Included in this are the genera, *Shorea*, *Doona*, *Hopea*, *Isoptera*, *Parashorea*, *Pentacme*, *Balanocarpus*, *Dryobalanops* and *Diopticarpus*.* In the other group the gum ducts are always scattered all over the wood—they may be single or in groups of a few. Occasionally one may come across in this group a concentric band of gum ducts but always accompanied by the scattered ones. Seven genera come under this; they are *Dipterocarpus*, *Vateria*, *Vatica*, *Anisoptera*, *Cotylelobium*, *Stemonoporus*,* *Pachynocarpus** and *Monoporandra*.*

From the description of the fossil recorded in this paper it will be noticed that it belongs to the second group. On making a comparative study of the genera under this group, based on the size and the distribution of vessels and of gum ducts, as well as the shape and the arrangement of rays and their individual cells, it has been found that the fossil shows the greatest affinity to the genus *Anisoptera*. As to tracing the fossil to a particular species of *Anisoptera* it could not be done for two reasons. Firstly, our knowledge of the anatomy of the *Dipterocarpaceae* is not at present complete, and secondly, the unsatisfactory preservation of the fossil does not allow the required measurements that are necessary for separating the species.

(3) Comparison with those previously recorded.

(a) INDIA.

In 1916 a fossil wood from the Irrawaddy (Tertiary) series of Burma was identified by Holden (18, 36) as *Dipterocarpoxylon burmense*. Later Gupta (16) re-examined and re-named it as *Irrawadioxylon burmense*. In a previous paper the author (6) has expressed his doubt regarding Gupta's identification and has also pointed out the affinity of Holden's original specimen to *Glutoxylon assamicum*. In any case, it is now certain that this fossil from Burma has been wrongly named as *Dipterocarpoxylon*. Sen (35) reported another fossil wood from Bengal and called it *Dipterocarpoxylon* after Holden. Since Holden's specimen was not correctly identi-

* Due to divergence of opinion amongst systematic botanists, the generic position of these four is still uncertain.

fied, it appears to be justified to conclude that Sen's specimen is not a true *Dipterocarpoxylon*.

In 1935 Gupta (17) reported another fossil wood from the Tertiary formations of Burma as *Dipterocarpoxylon holdeni*. The photomicrographs included in his paper did not show much affinity to the woods of the living *Dipterocarpaceae*. At my request Professor B. Sahni of Lucknow University has been kind enough to send me the slides of this fossil. I have examined them and am of opinion that *Dipterocarpoxylon holdeni* has not been correctly identified. To start with, it does not possess any vertical gum ducts. Nor does it show similarity to the woods of *Dipterocarpaceae* in size and distribution of vessels, of parenchyma and of rays. In the face of all these differences there does not appear to be any justification for taking it as one of the *Dipterocarpoxylon*.*

Recently Rode (33) described a fossil dicotyledonous wood from the Deccan Intertrappean beds and named it as *Dryoxylon mohgaœnse*. He did not attempt to show affinity of the fossil to living trees but simply recorded some of his observations. From what he has given in his paper it appears that the fossil from the Intertrappean beds does not belong to the *Dipterocarpaceae* nor to the fossil wood from the Garo Hills. From the above it would be seen that the fossil under investigation is the first specimen in India to be recorded as belonging to the family *Dipterocarpaceae*.

(*b*) OUTSIDE INDIA.

Different workers have used the name *Dipterocarpoxylon* in different senses and it seems here desirable to clear up this point before an enumeration is made of the various *Dipterocarpoxyla* that have so far been recorded from outside India. Kräusel (20, 21, 22, 23), Edwards (11) and Bancroft (1, 2) are of opinion that the name *Dipterocarpoxylon* should be used to include all fossil woods of the *Dipterocarpaceae*, while Den Berger (8, 9), Pfeiffer and Van Heuren (27) have gone further and divided the family into different genera or sub-groups and named them accordingly. In the opinion of the latter three *Dipterocarpoxylon* includes only two genera, *Dipterocarpus* and *Anisoptera*.

* I understand Dr. Gupta is soon going to re-examine this fossil critically, and if possible, determine its correct systematic position.

Altogether 17* fossil specimens have so far been reported as belonging to the *Dipterocarpaceae* and these are shown in the table below under the names they have at present:—

Table showing various fossil woods referred to Dipterocarpaceae *with their age.*

Serial No.	Species.	Country.	Age.
1	*Bredæa moroides*, Gœppert, 1854. (15) *Dipterocarpoxylon moroides*, Kräusel, 1926. (23). *Shoreoxylon moroides*, Den Berger, 1927. (9).	Java . .	Tertiary.
2	*Naucleoxylon spectabile*, Crie, 1888. (7). *Dipterocarpoxylon spectabile*, Kräusel, 1926. (23). *Dryobalanoxylon spectabile*, Den Berger, 1927. (9).	Java . .	Tertiary.
3	*Grewioxylon swedenborgii*, Schuster, 1910. (34). *Dipterocarpoxylon swedenborgii*, Kräusel, 1922. (20).	East Indies .	Tertiary.
4	*Dipterocarpoxylon tobleri*, Kräusel, 1922. (20). *Dryobalanoxylon tobleri*, Den Berger, 1923. (8).	South Sumatra	Tertiary.
5	*Dipterocarpoxylon* sp., Kräusel, 1922. (20). *Shoreoxylon djambiense*, Den Berger, 1923. (8). *Dipterocarpoxylon djambiense*, Edwards, 1931. (11).	South Sumatra	Tertiary.

* *Dipterocarpoxylon annamense*, Colani, has not been included in this list. For reasons see author's remarks in (6).

Table showing various fossil woods referred to Dipterocarpaceae *with their age*—contd.

Serial No.	Species.	Country.	Age.
6	*Dipterocarpoxylon* sp., (*tobleri* ?) Kräusel, 1922. (20). *Shoreoxylon kräuseli*, Den Borger, 1923. (8). *Dipterocarpoxylon kräuseli*, Edwards, 1931. (11).	South Sumatra	Tertiary.
7	*Cæsalpinioxylon palembangense*, Kräsuel, 1922. (20). *Shoreoxylon palembangense*, Den Berger, 1923. (8).	Sumatra .	Miocene.
8	*Dipterocarpoxylon javanense*, Kräusel, 1922. (21). *Dryobalanoxylon javanense*, Den Berger, 1927. (9).	Java . .	Tertiary.
9	*Dipterocarpoxylon gœpperti*, Kräusel, 1926. (23).	Java . .	Tertiary.
10	*Dryobalanoxylon* sp., Pfeiffer and Van Heurn, 1928. (27).	Java . .	Plio-Pleistocene.
11	*Dipterocarpoxylon* sp., Pfeiffer and Van Heurn, 1928. (27).	Java . .	Plio-Pleistocene.
12	*Shoreoxylon* sp., Pfeiffer and Van Heurn, 1928. (27).	Java . .	Plio-Pleistocene.
13	*Dipterocarpoxylon scebelianum*, Chiarugi, 1933. (5).	Italian Somaliland.	Plio-Pleistocene.
14	*Dipterocarpoxylon somalense*, Chiarugi, 1933. (5).	Italian Somaliland.	Plio-Pleistocene.
15	*Dipterocarpoxylon giubense*, Chiarugi, 1933. (5).	Italian Somali land.	Plio-Pleistocene.
16	*Dipterocarpoxylon africanum*, Bancroft, 1933 (1) and 1935. (2).	East Africa .	Tertiary.
17	*Dipterocarpoxylon garoense*, Chowdhury, 1938.	Garo Hills, Assam.	Tertiary.

Illustrations of these fossils as well as their descriptions have been critically studied. None of them shows all the anatomical characteristics similar to those of the fossil from the Garo Hills. *Dipterocarpoxylon gœpperti*, Kräusel, (23) shows some slight resemblance to the fossil in the cross section but the tangential sections are entirely different. Again, *Dryobalanoxylon spectabile*, Den Berger, (9) and this fossil show some agreement in their tangential view but their cross sections are not at all similar. In view of these facts it can, therefore, be concluded that the fossil from Garo Hills has no affinity with any of the *Dipterocarpoxyla* previously reported from outside India.

(4) Name and diagnosis.

A comparative study of the fossil G. S. I. Type No. 16502 with the living dicotyledons has shown its greatest affinity to the genus *Anisoptera*. Considering our imperfect knowledge of the anatomy of the living *Dipterocarpaceae* it does not at present appear to be judicious to give it that generic name. The fossil from the Garo Hills is, therefore, named *Dipterocarpoxylon garoense*, which means that it belongs to the order *Dipterocarpaceae* excluding the genera *Monotes* and *Marquesia*. Its specific diagnosis is given below :—

Dipterocarpoxylon garoense, sp. nov.*

Growth rings.—Indistinct.

Vessels.—Visible to the eye, medium-sized to rather large; tangential diameter of solitary vessels 169 $\pm 9\mu$, radial diameter 268 $\pm 8\mu$, more or less evenly distributed, usually 112 (138) single or groups per 25 mm. sq., in groups of 2-4 (7), 30 per cent. in pairs and the rest single; tylosed, occasionally filled with solid contents; perforation plate simple, horizontal or oblique; vessel elements with or without tail. Inter-vessel pit pairs fairly large, alternate, outline of border oval; aperture lenticular, horizontal or slightly oblique. Vessel-tracheid pits similar to inter-vessel pits. Vessel-ray pits two types: (1) one to a ray cell, usually large, (2) several to a ray cell, somewhat similar to inter-vessel pits but smaller, out-

* Description of the fossil given here is in accordance with the standard method of describing a wood by Chattaway (4), Rendle and Clarke (31). Figures included in the description are based on counts as given below :—

Vessel distribution 20 counts; tangential and radial diameter of vessels, 100; fibre length, 50; ray distribution, 25; ray width and height, 50.

line of the border small, round to oval, aperture oval to lenticular. Vessel-parenchyma pits similar to vessel-ray pits.

Tracheids.—Vasicentric in a single row, occasionally intercepted by parenchyma cells. Pits exactly like vessel, their size and shape depending on the adjacent cells.

Fibres.—Thick to very thick-walled, irregularly arranged, showing no definite alignment in cross section, occasionally filled with solid contents. Septate fibres not observed. Inter-fibre pits simple to bordered, outline of border round to oval, aperture slit-like. Fibres short, 978$\pm$56μ in length.

Parenchyma.—Not visible to the eye or with a hand lens, scanty to fairly abundant under microscope; (1) paratracheal in rows of 1-3 (mostly 2) intercepted by tracheids; (2) metatracheal irregular, in narrow or wide bands, occasionally surrounding gum ducts; (3) diffuse, rather scanty. Inter-parenchyma pits round to oval, small to large, one to many per cell.

Rays.—Visible to the eye, moderately numerous, 5 per mm., heterogeneous, occasionally containing solid deposit; moderately broad to broad, 5-8 cells, 98$\pm$23μ in width; height usually more than 15 cells, very low to low, 720$\pm$144μ; uniseriate rays and outer cells of the multiseriate rays squarish to oblong vertically; the inner cells procumbent, irregularly arranged. The rays occasionally vertically fused, running to considerable height. Pits between ray cells small, numerous, oval or nearly so.

Gum ducts.—Vertical gum ducts noticed. (1) Diffuse or scattered in groups of 2-3, (2) in tangential bands of considerable length.

5. General remarks.

Much has been written on the difficulty of identifying palæobotanical specimens based on isolated material. But it is doubtful whether one can always obtain complete material of foliar and reproductive remains to be sure of the specific naming of a fossil. In view of the progress made in plant anatomy within the last 50 years and of the certainty with which the isolated wood samples of the living species are now being identified in various laboratories, it appears to be possible to trace specimens of fossil wood to at least a genus or group of genera. According to this school of botanists the degree of certainty in the identification of a fossil wood will depend on the extent of our knowledge in the anatomy

of the family concerned. The order *Dipterocarpaceae* shows distinct anatomical characteristics by which its members can be easily distinguished from those of the others. Fossil woods possessing no gum ducts or only doubtful ones have in some cases been placed under *Dipterocarpoxylon*. Such rash identifications have caused only confusion, as can be seen from the past record. All anatomical details of a fossil wood must match with those of the *Dipterocarpaceae* before it can be placed with certainty under *Dipterocarpoxylon*.

The present distribution of the *Dipterocarpaceae* has been recorded by various systematic botanists and this question has been fully discussed by Bancroft (1) in her paper on "A contribution to the Geological History of the *Dipterocarpaceae*". Lately, Kanjilal and Das (19) have published a 'Flora of Assam' according to which only three genera, namely *Shorea*, *Dipterocarpus* and *Vatica*, occur in Assam. No mention is made by these authors of the genus *Anisoptera*, to which the fossil under investigation shows the greatest affinities. At present the *Anisopteras* are known to occur in Burma, Siam, Indo-China, Malay Archipelago and Philippine Islands, and the reason for their migration from western Assam is not well understood.

Dr. Fox's specimen from the Garo Hills is of great interest from the botanical point of view, for amongst the fossil woods so far reported from India, this alone shows in full detail the anatomical structure of the living *Dipterocarpaceae* and therefore would appear to be the first *Dipterocarpoxylon* to be recorded from India. From other countries, such as the Malay Archipelago and East Africa, a good many *Dipterocarpoxyla* have been reported. It was thought that a consideration of the age of these fossils from outside India might throw some light on the exact age of the fossil under investigation, but unfortunately no helpful clue could be obtained, for the *Dipterocarpoxyla* from outside India had been recorded from the Tertiary to the Recent and this is little more than what is already known about the age of the fossil in question.

(B) SPECIMEN G. S. I. No. K40/485.

(1) Description.

To start with it may be mentioned here that the preservation of this specimen has been so bad that its detailed anatomical study

was not possible. Whatever minute anatomy has been observed is recorded below :—

Growth rings are very difficult to distinguish. There is some suggestion of a tangential parenchyma band which cannot with certainty be taken for a demarcation of growth ring (Pl. 16, fig. 4). Moreover, the specimen is so small that it does not show more than one such band. *Vessels* are more or less evenly distributed. Some are in radial pairs but majority are single. In shape they are oval to circular (Pl. 16, figs. 4, 6). *Wood fibres* are arranged in somewhat radial rows. Their walls are thin to fairly thick (Pl. 16, fig. 6). *Parenchyma cells* are difficult to distinguish from the wood fibres. There appear to be some round the vessels but the patterns they form are not at all distinct. *Rays* are not prominent either to the eye or with a hand lens but they are fairly distinct under a high power microscope. They are more or less uniformly distributed, 2 to 3 seriate, heterogeneous and low in height (Pl. 16, fig. 5).

(2) Name and diagnosis.

The above anatomical data are too incomplete for any profitable comparison either with the woods of the living dicotyledons or with the dicotyledonous fossil woods that have so far been reported. In these circumstances it seems advisable to place it in the form genus *Dryoxylon*, Schleiden, and its diagnosis is given below :—

Specimen G. S. I, No. K40/485. DRYOXYLON sp.

A diffuse porous wood.

Growth rings.—Indistinct.

Vessels.—Medium sized to fairly large, visible to the eye; solitary or in radial pairs of 2-3 (mostly 2); tyloses not observed; perforation plate simple.

Wood fibres.—Thin to moderately thick walled, arranged in somewhat radial rows.

Parenchyma.—Distribution mostly indistinct; appears to be round the vessels and also in tangential bands.

Rays: Visible under high power of microscope, 2-3 seriate, heterogeneous and low in height.

SUMMARY.

1. Two dicotyledonous fossil woods from the Garo Hills of Assam are described and recorded.

2. The specimen G. S. I. Type No. 16502 has been intensively studied and its affinities to the living *Anisopteras* of *Dipterocarpaceae* are shown. Comparison of the fossil with those previously recorded from India and outside India is made and their possible affinities are discussed. G. S. I. Type No. 16502 appears to be the first specimen of *Dipterocarpoxylon* to be found in India and it is named as *D. garoense.*

3. Previous workers record occurrences of *Dipterocarpoxylon* from Tertiary to Recent age. So the age of *D. garoense* is in agreement with their findings. Moreover, palæontological investigation of the beds in which *D. garoense* has been found, does not show any disagreement.

4. The specimen did not allow any detailed study, due to its bad preservation. Its anatomical details, as far as it has been possible to observe, are recorded.

Grateful acknowledgments are due to the Director and Dr. C. S. Fox of the Geological Survey of India for giving the author an opportunity to study these fossil woods. Thanks are also due to Prof. B. Sahni and Dr. K. M. Gupta of Lucknow University for allowing the author to examine the slides of *Dipterocarpoxylon holdeni* Gupta.

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EXPLANATION OF PLATES.

[All photomicrographs are from untouched negatives.]

PLATE 15.

Dipterocarpoxylon garoense, sp. nov., G. S. I. Type No. 16502.

FIG. 1. Transverse section showing distribution of vessel, rays and vertical gum ducts. Note the arrangement of gum ducts at the right hand corner (Gd). ×10.

FIG. 2. Transverse section showing distribution of small (Sv) and large vessels in comparison with that of gum ducts (Gd.) ×40.

FIG. 3. Transverse section showing parenchyma and tracheids round the vessels. Note also the distribution of metatracheal parenchyma cells. ×75.

FIG. 4. Transverse section showing a pair of gum ducts surrounded by rows of parenchyma cells. ×35.

FIG. 5. Tangential section showing distribution, width and height of rays. Note also the size and shape of the cells forming different types of rays. ×50.

FIG. 6. Tangential section showing tyloses in the vessels. ×110.

PLATE 16.

Dipterocarpoxylon garoense, sp. nov., G. S. I. Type No. 16502.

FIG. 1. A vessel element showing inter-vessel pits. ×90.

FIG. 2. Radial section showing inter-vessel pits (Ivp) and fungal hyphæ (H.) ×440.

FIG. 3. Radial section showing vessel-ray pits (Vrp). Note their distribution and size. ×440.

Dryoxylon sp., G. S. I. No. K40/485.

FIG. 4. Transverse section showing general structure of the wood. ×10.

FIG. 5. Tangential section showing size and distribution of rays. Note the shape of individual cells of rays. ×75.

FIG. 6. Transverse section showing distribution and arrangement of wood fibres. ×35.

ON SOME FOSSIL FISH-SCALES FROM THE INTER-TRAPPEAN BEDS AT DEOTHAN AND KHERI, CENTRAL PROVINCES, BY SUNDER LAL HORA, D.Sc., F.R.S.E., F.N.I., *Assistant Superintendent, Zoological Survey of India, Calcutta.* (With Plates 17 and 18.)*

CONTENTS.

INTRODUCTION.

The fossil fish-scales described below were collected by Mr. H. Crookshank, Superintending Geologist, Geological Survey of India, from the Inter-trappean beds about ¾ mile to the east of Deothan (22° 19′ : 77° 35′) and about ¼ mile to the east of Kheri (22° 22′ : 77° 29′) in the Central Provinces. In his memoir on the 'Geology of the Northern Slopes of the Satpuras between the Morand and the Sher Rivers' (1936, p. 288), he made a reference to my tentative conclusions regarding the identity of some of the fish scales, but later he collected much more varied material. A brief reference was also made to these scales by Crookshank, Sahni, and the writer at the General Discussion on the 'Age of the Deccan Trap' held at the 24th meeting of the Indian Science Congress at Hyderabad in 1937. In the following account the various types of scales are described and their probable relationships elucidated. Opportunity has also been taken to describe some other infra- and inter-

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trappean fish-material in the collection of the Geological Survey of India which had not previously been studied by any specialist.

For the arrangement of the material I have followed Jordan's (1923) system of classification. The evidence furnished by these fish-remains in regard to the age of the beds and the ecological conditions under which the fish lived during that period are discussed at the end of the paper.

It may be indicated at the very outset that the study of fish scales is not sufficiently advanced to enable a specific determination to be made of the various types represented in the material; their broad relationships are, however, quite clear and in some cases it has even been possible to refer them to genera or to very closely allied forms. The great value of the study of fish-scales for purposes of identification and classification is being more and more realised as the science of lepidology makes progress, for, like all other structures of a fish organisation, scales also vary and exhibit different patterns of ornamentation in various groups of fishes. The palæontological value of fish-scales appears to me on a par with that of fossil seeds or teeth. In fact, in most cases it should be more valuable than that of teeth or small fragments of bone.

In determining the fossil material I had to examine the scales of a large number of living forms, and where a similarity with the fossil scales was found, both the present-day and the fossil scales are figured side by side to bring out the full significance and stability of their characters.

Mr. Crookshank has kindly given me the following note concerning the Intertrappean beds at Deothan and Kheri :—

"These beds vary in lithology from place to place but the chief types at Deothan are black carbonaceous and buff ferruginous shales. Both these varieties are fossiliferous and contain numerous irregular masses of volcanic ash. At Kheri the fossils are found in calcareous shales.

"In both areas the Intertrappean bed is believed to overlie the basal flow of the Deccan trap.

"Other localities in the same region where fossiliferous Intertrappeans were noted are: Khuramba (22° 22′ : 77° 29′), south by east of Patlai (22° 23′ : 77° 33′), and east of Napupura (22° 21′ : 77° 37′). None of these areas has been carefully searched. It is quite likely that a thorough search of them would bring to light further fossil remains of importance.

"As regards Deothan and Kheri the outcrops were carefully searched, but no attempt was made to quarry the fossiliferous shales as it was found that the unweathered material was not fissile and the fossils in it were, therefore, very fragmentary. It is probable that good fossils might be obtained from the fresh material

if it were heated and later quenched, as this would make it split along the planes where the fossils occur.

"As well as the fish remains in these beds there are plant and insect remains, Cypridae, and Gastropods. These fossils have not so far proved to be of much interest."

I am very grateful to Mr. Crookshank for the opportunity of examining this interesting material and for his valuable criticism and helpful suggestions.

The whole of the material dealt with in this paper is preserved in the collection of the Geological Survey of India.

SYSTEMATIC DESCRIPTION.

Superorder TELEOSTEI.

Order ISOSPONDYLI.

Suborder CLUPEOIDEI.

Family *CLUPEIDAE.*

(Plate 17, fig. 3; plate 18, figs. 8, 9 and 10; text-figs. 1 and 2.)

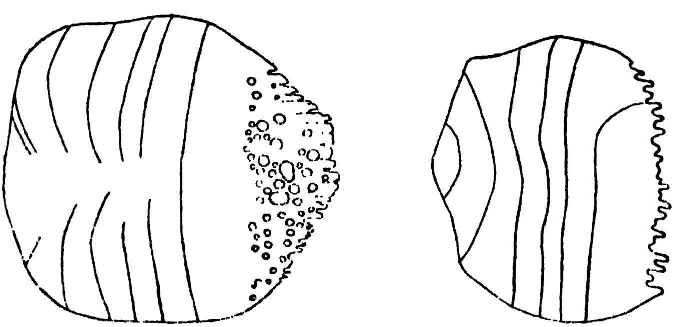
Material.- Specimens with transverse radii widely interrupted in the middle, Nos. K32/154, K32/156, K32/159, K32/162, K40/291, K40/292, K40/293, K40/294 (from Deothan); specimens with transverse radii complete, Nos. K32/162, K54/293 (from Deothan).

TEXT-FIG. 1.—Two types of fossil Clupeoid scales.

a. A scale (K32/159) with transverse radii widely interrupted. ×18½; *b.* A scale (G 152) with transverse radii complete. ×*ca* 11.

There are a large number of small, fragmentary Clupeoid scales in the collection, but there is not a single complete specimen.

Two types of scales can be readily distinguished; (i) those in which the transverse radii are widely interrupted in the middle (Plate 17, fig. 3; text-fig. 1*a*) and (ii) those in which the transverse radii are complete (Plate 18, figs. 8, 9 and 10; text-fig. 1*b*). In both cases the extremely fine circuli are more or less transverse and meet the margins at right angles or somewhat obliquely. Both types of scales are found in the genus *Clupea* Linn. and the nature of the transverse radii is often utilised in distinguishing species of these commercially important fishes, most of which superficially appear to be very much alike. Weber and de Beaufort (1913, pp. 76, 81) have figured similar scales (text-fig. 2), while Cockerell (1913, p. 123) has given a good general description of both kinds.



a. *b.*

TEXT-FIG. 2.—Scales of the two living species of *Clupea* Linn. (After Weber and de Beaufort).

a. Clupea (*Harengula*) *fimbriata* (C. V.). ×6; *b. Clupea* (*Harengula*) *moluccensis* Blkr. × 6.

Remarks.—The Clupeidae comprise a great variety of marine forms and are found practically all over the world. A number of species, such as the American Shad and the Indian Hilsa, enter the mouths of large rivers at certain seasons and give rise to immense fisheries. Though some representatives of the family have been recorded from the Lower Cretaceous, *Clupea* is, according to Zittel (1932, p. 155), "not certainly known below the Upper Eocene of Monte Bolca, near Verona". In view of the occurrence of the scales of *Clupea* both in the Infra- and Inter-trappean beds, however, this view may have to be revised.

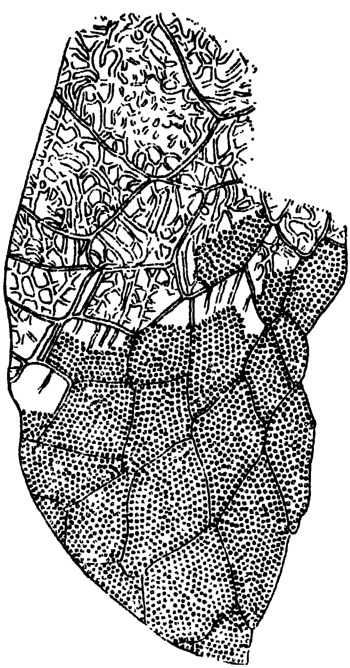
Suborder OSTEOGLOSSOIDEA.

Family *OSTEOGLOSSIDAE*.[1]

(Plate 17, figs. 7 and 8; text-figs. 3 and 4.)

Material.—Specimen No. K29/631 (two pieces), and two more pieces (from Deothan).

There are altogether four fragments of scales which I refer to the family Osteoglossidae. The scales of this family are large and thick and are composed of mosaic-like pieces. The largest piece in Mr. Crookshank's collection (pl. 17, fig. 7) is about 16 mm. in its greatest length and as this fragment represents more than half of the scale, it may safely be presumed that the diameter of the scale would be about 16 mm. The small mosaic-like pieces are rhomboidal; they are approximately 3 to 4 mm. in length and 1½ to

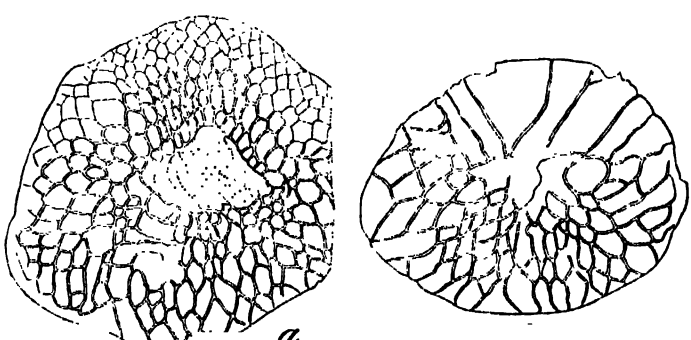


TEXT-FIG. 3.—A fragment of an Osteoglossid scale (K29/631), genus *Musperia* Sanders. ×7.

[1] Jordan (1923) notes that the Osteoglossidae, the Arapaimidae and the Clupisudidae should perhaps be merged into one family.

2 mm. in width. Some of the pieces at one end are considerably larger. The longer axis of each piece points towards the centre and the periphery. Each piece is marked with very fine circuli which are moniliform throughout. In places where the rough, greyish skin has peeled off, the bony portions exhibit a more or less vermiform sculpture (text-fig. 3).

Remarks.—Of all the bony fishes, the Osteoglossidae are unique in regard to their present-day geographical distribution. The living members of the family are found in South America [*Osteoglossum* (Vandelli) Cuvier and *Arapaima* Müller], Africa [*Heterotis*[1] (Ehrenberg) Müller], Siam (*Scleropages* Günther), Indo-Australian Archipelago (*Scleropages*) and Australia (*Scleropages*). These are among the largest freshwater fishes known; the South American *Arapaima* reaches about 15 feet in length. The four living genera have only five species, of which two belong to *Scleropages*. *S. formosus* (Müll. & Schl.) is found in Sumatra, Banka and Borneo and has only recently been recorded from Siam (Smith 1931, p. 177); while the other species—*S. leichhardti* Günther—is mainly known from Queensland, but on the basis of a photo it has also been recorded from New Guinea (Weber & de Beaufort, 1913, p. 14). This remarkable discontinuous distribution of the family is more or less parallel to the distribution of the living Dipnoan fishes, and shows the great antiquity of the Osteoglossidae.



TEXT-FIG. 4.—Fossil Osteoglossid scales from Sumatra. After Sanders. *a.* Scale of *Scleropages* sp.; *b.* Scale of *Musperia radiata* Sanders.

The geological history of the family Osteoglossidae takes it back to the Eocene period (Zittel, 1932, p. 153). *Phareodus* Leidy

[1] Jordan (1919, p. 202) points out that *Clupisudis* Swainson should replace *Heterotis* Ehrenberg.

(=*Dapedoglossus* Cope) is known from the Eocene Green River shales of Wyoming, U. S. A.; *Brychaetus* A. S. Woodw. from London clay and Sheppey and *Scleropages* from the Tertiaries of Sumatra.

In her monograph on the Tertiary freshwater fishes of Middle Sumatra, Sanders (1934) has published photographs of complete scales of *Scleropages* and of her new genus *Musperia*. The structure of the scales of these two genera differs in several respects, some of which are noted below.

In *Scleropages* there is a fairly large nuclear area in the centre (text-fig. 4*a*) which appears to be devoid of smaller pieces and only covered with moniliform striations; the mosaic pieces are relatively small and more or less ovoid or squarish in outline. In *Musperia*, on the other hand, there is no clear nucleus, and the rhomboidal, mosaic pieces are fairly large, especially towards one end of the scale.

A comparison of the text-figures 3 and 4 shows that the fossil scales obtained by Mr. Crookshank correspond with those of *Musperia* in all important respects noted above. In discussing the affinities of her new genus, Sanders has pointed out certain resemblances between *Musperia* and the North American Eocene genus *Phareodus* on the one hand and with the African genus *Heterotis* on the other. It would thus appear tentatively that the original stock which migrated from the north to the south may have consisted of forms like *Musperia*, which is now extinct and whose remains are known from Sumatra on the one hand and Peninsular India on the other. This genus was probably a descendant of *Phareodus* and in its further wanderings along two definite routes it gave rise to *Scleropages* in Siam, the Indo-Australian Archipelago and Australia in the south-east and to the African and South American genera in the south-west. The same two routes of wanderings seem to have been followed by the Dipnoan fishes at an earlier period of the earth's history. It may here be noted that fossil remains of *Ceratodus* Ag. are known from the Kota-Maleri beds of India (*C. hislopianus* Oldham); these beds are in the Godavari valley and are placed in the Upper Gondwana period.

The Osteoglossidae are recorded here from India for the first time; and this is of special significance from a zoogeographical point of view. As indicated above, it points to a possible route of migration by which these large fishes may have spread from India to Africa and later to South America.

Series OSTARIOPHYSI.

Order EVENTOGNATHI.

Family *CYPRINIDAE*.

(Plate 17, fig. 6; text-fig. 5.)

Material.—Specimen No. K32/149 and its counterpart No. K32/150 (from Deothan).

Though there is only one fragment of a Cyprinid scale, its essential structural features are very clear. It seems to have been oval in outline, about one and a half times as long as broad. The nuclear area is small and somewhat eccentric in position. The scale is provided with a large number of radii which are distributed in all directions. The circuli are very fine and compactly arranged.

TEXT-FIG. 5.—A fragment of a fossil Cyprinoid scale (K32/149). ×17.

Remarks.—The structure of the scale strongly suggests its very primitive nature and leads to its inclusion in the subfamily Abramidinae. In the main, it corresponds with the scale of *Leuciscus œningensis* Ag. from the Upper Miocene figured by Zittel (1932, p. 157) after Winkler, but its detailed structure and the form are quite different. I have not been able to assign it definitely to any genus, as the scales of most of the living genera have not been so far described.

The Cyprinidae are at present found in great abundance in the fresh waters of the Old World and North America, but are totally absent from South America. In the fossil state they are found from the Lower Eocene to the Pleistocene. Most of the fossil genera are represented by living forms.

Superorder ACANTHOPTERYGII.

The Acanthopterygii, which include the large group of Perches, are abundantly represented in the existing fauna. In the fossil material collected by Mr. Crookshank there are at least seven types of scales which can be referred to this group of fishes. According to Cockerell (1913, p. 143) a typical Acanthopterygian scale,

> " is more or less quadrate, with the nucleus subapical, the basal circuli fine and transverse, the basal radii strong, spreading out like a fan, and the apical area covered with fine dentiform structures which can be counted in rows obliquely or transversely, and on the margin form a series of fine teeth."

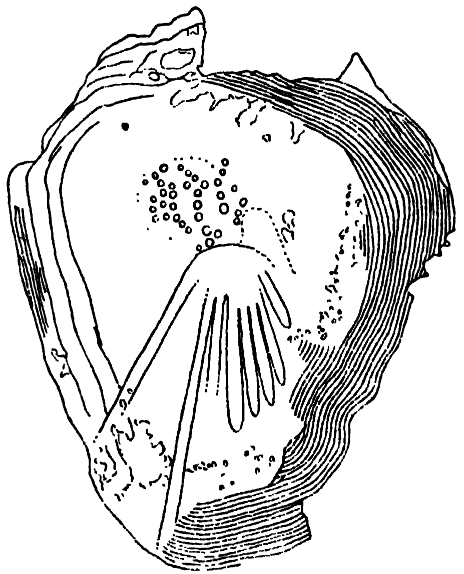
From the above it will be noticed that the scales of *Eoserranus hislopi* described by A. S. Woodward (1908) from the Lameta beds at Dongargaon in the Central Provinces differ from a typical Acanthopterygian scale in the fact that they are cycloid and in them the basal portion, marked with well-developed radii, is much narrower than the apical portion. Woodward's description of the scale (text-fig. 6) is as follows :

> " The scales appear to have been cycloid and rather small. As shown in the type specimen, their exposed sector is ornamented with fine, radiating ridges. Their inner face as shown in impression is marked in the covered portion with radiating furrows."

The *Eoserranus*-type of scale, therefore, seems to represent a primitive stage in the development of an Acanthopterygian scale. According to Cockerell (*loc. cit.*) :

> " The toothed or ctenoid feature appears to be derived from the longitudinal apical circuli which become modified and segmented, the terminal segments

especially taking the form of teeth. It is this segmented arrangement which gives the apical area in Acanthopterygians its special character, resembling very much the arrangement of bracts in the heads of some composite flowers."



TEXT-FIG. 6.—A scale of *Eoserranus hislopi* A. S. Woodw. (From the type-specimen, No. 9365 G. S. I.). ×5½.

In my preliminary report to Mr. Crookshank I referred a large scale (pl. 17, fig. 5, text-fig. 8) in his collection to *Eoserranus*, but a careful examination with proper illumination has shown that it is not a cycloid scale. Its general outline is also different from that of an *Eoserranus* scale. In fact, all the Acanthopterygian scales in Mr. Crookshank's collection conform to the general type noted above. There is such a great diversity of Acanthopterygian fishes that it is with great difficulty, and not without hesitation, that I have referred them to any definite genera. Their position in the families noted below, however, appears to be fairly certain.

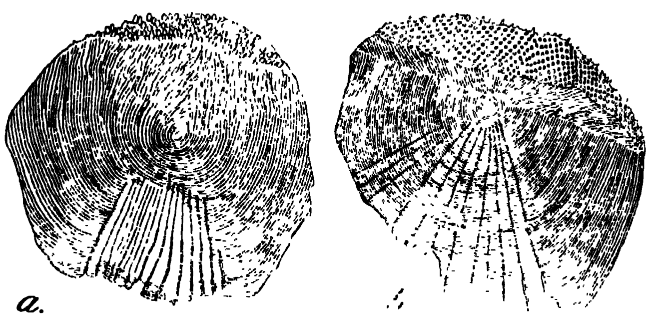
Order LABYRINTHICI

Family *POLYACANTHIDAE.*

(Plate 17, fig. 4; text-fig. 7*b*.)

Material.—Specimen No. K32/147 (from Deothan).

It is an almost complete scale (text-fig. 7*b*), with part of the apical portion covered by skin. Structurally the scale can be



TEXT-FIG. 7.—A Polyacanthid scale and an allied fossil scale (K32/147). *a*. Polyacanthid scale. ×8; *b*. Fossil scale allied to that of the Polyacanthidae. ×8½.

divided into three regions, (i) spiny apical portion; (ii) an area with fine radiating striae between the apical portion and the nucleus; and (iii) the basal area marked with fine circular striae which extend round the nucleus also. There are about a dozen fine, basal radii, of which eight extend almost to the nucleus while the remaining four are shorter. Some of the radii are interrupted in their course. The apical teeth are very small.

Remarks.—I have not been able to assign any definite generic position to this scale. While investigating the structure of a large number of freshwater Acanthopterygian scales I found some points of similarity between the fossil scale and that of *Polyacanthus* (K. & v. H.) Cuvier and Valenciennes (text-fig. 7*a*). Cockerell (1913, p. 164) described the scale of the Labyrinthid genus *Anabas* Cuvier and found the same divisions of the scale into three areas. The apical area is beset with linear, spine-like structures, of which the lateral ones are often continuous at the base with the circuli. The apical radii are widely spaced and are about 15 in number.

The scale of *Polyacanthus* appears to be much more specialised than that of *Anabas*; the present-day geographical distribution of the two genera also shows that the latter is certainly a more ancient form. *Anabas* (including the genera *Spirobranchus* Cuvier and *Ctenopoma* Peters) is found in south-eastern Asia and Africa, while *Polyacanthus* is only found in Ceylon, Singapore, Java, Sumatra and Borneo.

So far as I am aware no fossil Labyrinthid remains have hitherto been described.

Order PERCOMORPHI.

Series KURTIFORMES.

Family *SERRANIDAE.*

(Plate 17, fig. 5; text-fig. 8.)

Material.—Specimen No. K29/629 (from Deothan).

The scale is represented by an impression of a part of its area. The entire scale must have been about 12 mm. in length and 11 mm.

TEXT-FIG. 8.—Impression of a fragment of a Serranid scale (K29/629). ×5.

in width. The nucleus is subapical and, though small in area, is clearly defined. The apical ctenoid area is also well marked, showing several rows of small, clearly defined, sharp spines. The circuli are very fine and compactly arranged. There are about 18 delicate radii, all of which start from near the nucleus and extend towards the periphery for a considerable distance; some even reach the margin.

Remarks.—In Cockerell's (1913, p. 143) identification table of the Acanthopterygian scales, the following characters are noted for a Serranid scale:

(i) Basal radii spreading.
(ii) Basal margin not deeply lobed.
(iii) Basal area not beset with linear, spine-like structures.
(iv) Apical margin provided with many sharp and small teeth.

Judged by these features, the fossil scale impression is referrable to the family Serranidae. Though the earliest known Serranid—*Prolates* Priem—dates from the Upper Cretaceous, numerous fossil representatives occur in the Tertiary formations of Europe and North America. I have indicated above (*vide supra*, p. 275) that *Eoserranus* is probably a very primitive representative of the family. The specimen under report possesses a highly specialised structure, so is probably younger than *Eoserranus* in the scale of geological history.

Incertae Sedis.

There are two other types of scales in the collection which, though quite distinct from those of the Serranidae, may be described in this place.

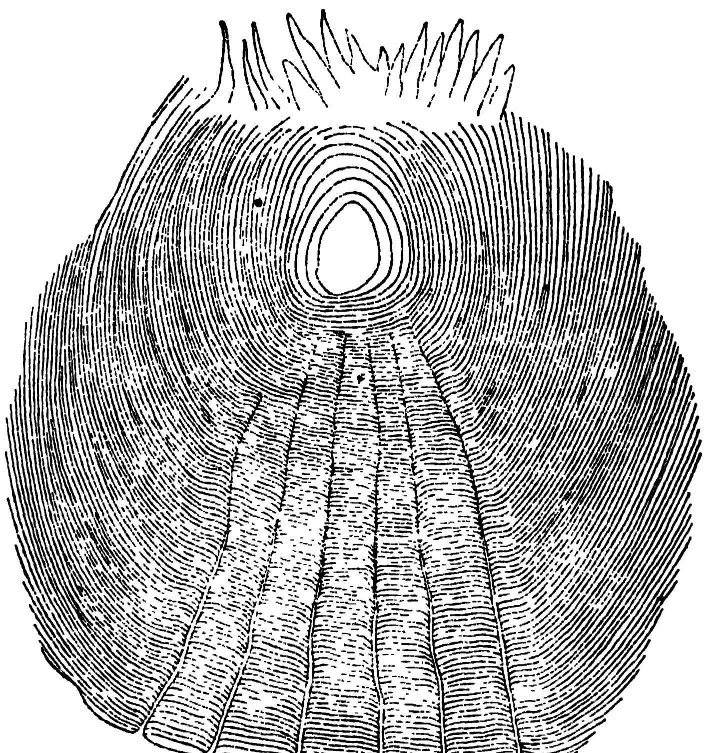
TYPE A.

(Plate 18, fig. 5; text-fig. 9.)

Material.—Specimen No. K40/286 (from Deothan).

This is a small, almost complete scale. Excluding the apical spines, it is almost as long as broad. The apical teeth seem to form a single row of about 15 teeth. A well formed tooth is about three times as long as broad at the base. The nucleus is well defined and subapical. The scale is provided with a large number of fine

circular striae, a few of which are concentrically arranged round the nucleus. There are only six, well-defined, basal radii which



TEXT-FIG. 9.—A primitive Acanthopterygian fossil scale (K40/286). ×93.

are widely spaced and seem to run almost parallel to one another. The lateral margins of the scale are incomplete but in general outline it appears to have been circular.

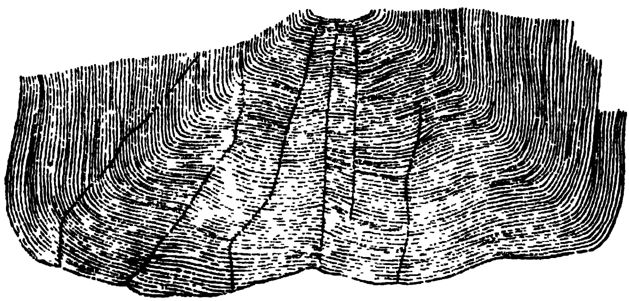
Remarks.—In the present state of our knowledge of lepidology, I am unable to refer this scale to any Acanthopterygian family From the arrangement of the basal radii and the nature of the apical teeth, this scale appears to be of a somewhat primitive type. It shows a certain amount of resemblance to the scales of the family Mullidae.

TYPE B.

(Plate 18, fig. 6; text-fig. 10.)

Material.—Specimen No. K40/283 (from Kheri).

This is only a fragment of the basal portion of a large scale about 9·6 mm. in width. The basal radii are delicate and few in number. The circular striae are very fine and closely set.



TEXT-FIG. 10.—Basal part of a large, fossil, Acanthopterygian scale (K40/283). ×10½.

Remarks.—It is very difficult to express an opinion about the relationships of this fragment. It is described and figured here merely because it appears to represent a large scale of a very distinct type, differing from all the other scales in the collection.

Family *NANDIDAE.*[1]

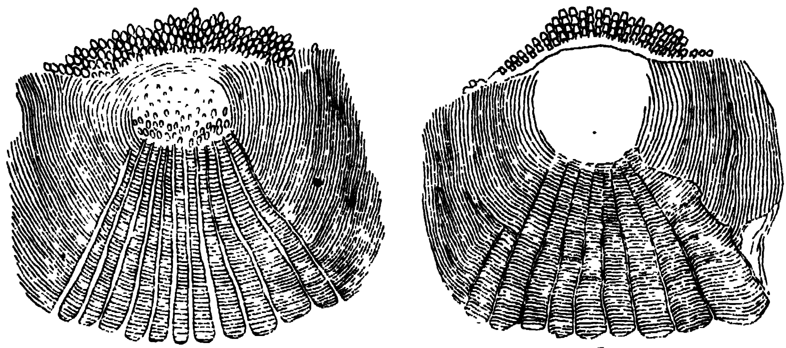
(Plate 17, fig. 2; text-fig. 11.)

Material.—Specimens Nos. K29/628, K40/287 (from Deothan); K40/285 (from Kheri).

These are small, subquadrate scales of the Percoid type with a subapical nucleus and strong basal radii. The number of radii varies from scale to scale. The nuclear area is fairly large and the radii, all of which are complete, arise at short intervals from the basal margin of the nucleus. The circuli are fine and closely set. There are several rows of short, blunt spines in the apical region.

[1] In the case of the genera included in the family Nandidae, Jordan (1923, p. 202) remarked that the group may require further division. By certain authorities it is now divided into the family Nandidae for *Nandus* C. V. and the family Pristolepidae for *Pristolepis* Jerdon, *Badis* Bleeker, etc. I have followed the latter arrangement.

Remarks.— Superficially these scales appear to resemble those of *Anabas* Cuvier (*vide* Cockerell 1913, p. 164), but the main difference lies in the disposition of the circuli. In *Anabas* " the basal



a. b.

TEXT-FIG. 11.—A fossil and a present-day Nandid scale.
a. Fossil scale (K29/628). ×24; *b.* Scale of *Nandus nandus* (Ham.). ×20.

circuli are dense, the lateral ones rather widely spaced and those at the sides of the apical field strong and very far apart ". In the fossil scales they are uniformly distributed. Moreover, the ctenoid patch of *Anabas* is of a totally different nature. In comparing the fossil scales (text-fig. 11 *a*) with those of the living forms I found a great general similarity between them and the scales of *Nandus* Cuvier and Valenciennes (text-fig. 11 *b*). The only difference lies in the fact that in *Nandus* the basal radii are not so strong and some of them may be incomplete.

Though the Nandidae, as restricted at the present day, are found in the Great Sunda Islands, Malay Peninsula, Burma and India, their close allies of the family Polycentridae are found in West Africa and South America.

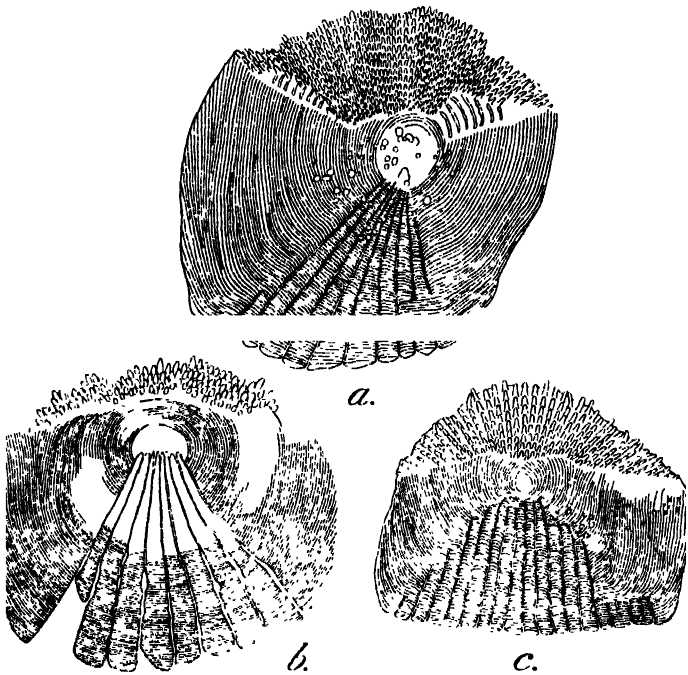
So far as I am aware, no fossil remains of the families Nandidae and Polycentridae have been described so far.

Family *PRISTOLEPIDAE*.

(Plate 17, fig. 1; text-fig. 12.)

Material.—Specimens Nos. K29/629, K32/157, K40/288, K40/289, K40/290, K40/292, K40/295, K40/296 (from Deothan); K31/546, K40/284 (from Kheri).

These small Percoid scales are similar to those of the Nandidae described above. The nuclear area is relatively smaller. The basal



TEXT-FIG. 12.—A fossil and two present-day scales of the family Pristolepidae.
a. Scale of *Pristolepis marginatus* Jerdon. ×8½; *b.* Fossil scale (K29/629). ×17½
c. Scale of *Badis badis* (Ham.). ×14½.

radii are long and converge in the nucleus. The number of radii varies considerably but they are never less than 8 or more than 15. As a rule, all the radii are complete.

Remarks.—There appears to be a general similarity between the fossil scales and those of the genera *Pristolepis* Jerdon and *Badis* Bleeker. This similarity is more marked between the fossil scales and those of *Pristolepis*. From a consideration of the present-day distribution of the two genera, it appears probable that *Pristolepis* is more ancient than *Badis*. The former is found in South India, Burma, Siam, Cochin China and the Sunda Islands, whereas the latter is confined to India and Burma.

So far as I am aware no fossil remains belonging to this family have been described so far.

GEOLOGICAL AGE OF THE INTER-TRAPPEAN BEDS AND SOME OBSERVATIONS ON THE ECOLOGICAL CONDITIONS OF THAT PERIOD.

In a short preliminary article I (1938) have already briefly expressed my views on the probable age of the Deccan trap as evidenced by the fossil fish-remains, but below is given a detailed analysis of the main points at issue.

From a stratigraphical point of view the above results may be summarised as follows :—

Family Clupeidae : Genus *Clupea* Linn.	Upper Eocene to Recent.
Family Osteoglossidae : Genus *Musperia* Sanders.	Tertiary.
Family Cyprinidae : Genus ? Abramadinae .	Lower Eocene to Recent.
Family Polyacanthidae : Genus ? *Polyacanthus* C. V.	Recent; no fossils previously recorded.
Family Serranidae : Genus ? *Serranus* Cuv. .	Tertiary to Recent.
Family Nandidae : Genus *Nandus* C. V. .	Recent; no fossils previously recorded.
Family Pristolepidae : Genus *Pristolepis* Jerdon.	Recent; no fossils previously recorded.

Of the seven families to which Mr. Crookshank's material has been assigned, the first two belong to the Isospondyli, and therefore represent a very primitive stock of the teleostean fishes. Though the Clupeidae go back to the Lower Cretaceous, there is no doubt that the fossil fish scales referred to the family belong to the genus *Clupea*, which, according to Zittel, is not known from below the Upper Eocene. For the determination of the age of the beds, the evidence furnished by the Osteoglossidae is very conclusive, for the fossil remains of this remarkable family are not known from below the Eocene. The Cyprinidae, of which there is only one scale, also go back to the Eocene. The Serranidae are known in the fossil state mainly from the Tertiary formations. So it would seem that these beds cannot possibly be older than the Lower Eocene.

The present-day geographical distribution of the Polyacanthidae, the Nandidae and the Pristolepidae, of which no fossil remains had hitherto been described, throws some light on the upper limit of these beds. The Polyacanthidae and the Nandidae are represented by allied forms in Tropical Africa; in the case of the former the genus *Anabas* Cuvier (family Anabantidae) is common to Africa and south-eastern Asia. Of the two families, the Nandidae would seem to be older, as some allied forms are found in South America

as well. The family Pristolepidae is confined to south-eastern Asia. These facts of distribution suggest that the Labyrinthid fishes, such as the Anabantidae, Polyacanthidae, etc., and the Nandidae wandered over to Africa when there was still a land connection between India and Africa. The relative localised distribution of the Pristolepidae, on the other hand, suggests that these fishes were probably evolved after the severance of the connection between the two adjacent land masses. The conclusion which may, therefore, be drawn from the fossil records of these families is that the Inter-trappean beds at Deothan and Kheri were probably laid down when the land-bridge between India and Africa had already disappeared.

The only other fossil fish associated with the Deccan traps were reported from the Lameta beds at Dongargaon by A. S. Woodward (1908) who described one new species of each of the following genera: *Eoserranus* A. S. Woodw., *Lepidosteus* Lacépède and *Pycnodus* Ag. From these records he concluded that:

"Although the Lameta fish-remains are not very satisfactory from the zoological standpoint, they are quite adequate for geological purposes. No true Percoid has hitherto been recognised in a typically Cretaceous formation in any part of the world; the oldest member of the group, as already remarked, being *Prolates* from the Montian of France. *Eoserranus* must therefore be regarded as a Tertiary type of fish. *Lepidosteus* is also typically Tertiary, differing essentially from the numerous Secondary ganoids to which it is related, by its highly specialised vertebrae. It ranges from the Lower Eocene to the Lower Miocene in Europe, and from the Eocene to the present day in North America; but has not previously been found in Asia. While *Eoserranus* and *Lepidosteus* can hardly be older than the beginning of the Tertiary period, the *Pycnodont*, according to the European standard, cannot be later than the close of the Eocene. The age of the Lameta fish-fauna is therefore fixed to be between the Danian Cretaceous and the Upper Eocene."

It is worthy of special remark that Mr. Crookshank did not find in the Inter-trappean beds at Deothan and Kheri any representative of the fauna described by Woodward. Whereas Woodward described two Ganoids and one Teleostean fish, in Mr. Crookshank's material there are Teleostean fishes only. I have now found remains of Clupeoid scales in the material collected by Hislop and other earlier workers from the various Infra and Inter-trappean beds of the Central Provinces. The Ganoids are a very ancient race, but from the beginning of the Cretaceous period their dominant position became more and more displaced by the Teleosteans. By the beginning of the Tertiary period an almost complete change

over of the faunas had taken place and the Ganoids were then represented only by a few forms. It may, however, be noted that *Lepidosteus* and *Amia* continued to flourish for a considerable period, as their fossil remains are recorded for the last time from the Lower Miocene of Europe. They are among the few living genera of the Ganoid fishes. On *a priori* grounds it is clear that Woodward was dealing with a much more primitive fauna than that investigated by the present writer. Woodward's material was collected by Hislop (1861, p. 196), and it seems worth while to enquire into the history of this collection. Hislop made the following observations with regard to the remains of fishes:

"The remains of fishes at Tákli and Pahádsingha consist chiefly of detached scales, some being Ganoidan and other Cycloidan. In the subtrappean yellow limestone of Dongargaum, sixteen miles E. S. E. of Chikni, the impression of a fish was found about 6 inches long and 1·8 inch in the broadest part, which must have been covered with cycloid scales, of a pattern that Sir P. G. Egerton had never seen. The same locality yielded the head of a fish about 9 inches long, with a produced muzzle, armed with sharp sauroid teeth, and rows of smaller ones. A fragment of bone, with 21 of apparently the very same smaller teeth, was dug out from the intertrappean of Tákli. According to Sir Philip, the ichthyolite most nearly allied to this is the *Sphyrænodus* of the London clay. In the Dongargaum limestone there was also embedded a portion of a Ganoid fish, *Lepidotus* or *Lepidosteus* (?) which is 6 inches broad, and when perfect was probably 2 feet long. This seems to be the species which has left so many of its scales in the intertrappean of Takli and Pahádshingha. A separate vertebra of a fish from the subtrappean red clay of Phisdura, 8 miles E. of Chikni, measures ·7 inch in diameter."

In the above passage Hislop refers to three types of beds and enumerates the fossil fish-remains collected from each, but Woodward apparently dealt with only the fish-remains obtained from the Lameta beds at Dongargaon. If, however, the Dongargaon material collected by Hislop is listed with the material from the same beds examined by Woodward there appear to be some inconsistencies. The following table illustrates my point:

Material collected by Hislop and noted in the passage quoted above.	Specific identification by Woodward.	Material examined by Woodward.
Impression of a fish, about 6 inches long and 1·8 inch in the broadest part, which must have been covered with cycloid scales. (*Not examined by Woodward.*)	*Eoserranus hislopi* A. S. Woodward.	One fragment of trunk; several specimens showing parts of head, and one showing scale impressions.

Head of a fish about 9 inches long with a produced muzzle, armed with sharp sauroid teeth, and rows of smaller ones.	*Lepidosteus indicus* A. S. Woodward, (figured by Woodward, pl. i, fig. 8).	Skull and a group of head-bones with scales and vertebrae.
A portion of a Ganoid fish, *Lepidotus* or *Lepidosteus* (?) which is 6 inches broad.	*Lepidosteus indicus* A. S. Woodward. (Portions figured by Woodward, pl. i, fig. 9, *a-d*).	
	Pycnodus lametae A. S. Woodward.	One skull.

It would thus appear that Woodward examined more specimens from Dongargaon than are noted to have been collected by Hislop in the passage quoted above. Presumably at some later date Hislop may have made further collections of fish-remains from the Dongargaon beds.

From the sub-trappean red clay of Phisdura, Hislop obtained a vertebra, about ·7 inch in diameter, which does not appear to have received the attention of any palæontologist so far. The specimen is not present in the collection of the Geological Survey of India, so I am unable to say anything about its systematic position.

From the Inter-trappean of Tákli and Pahársingha Hislop obtained detached Ganoid and cycloid types of scales. Further, a fragment of bone with 21 small teeth, was also obtained from the Inter-trappean beds at Tákli; unfortunately this material has not yet been studied by any specialist.

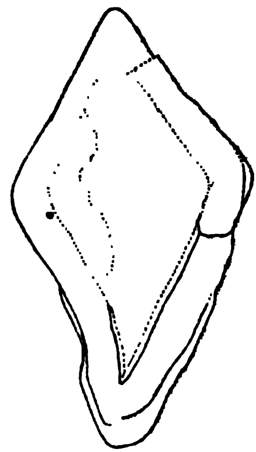
Besides some of the Dongargaon specimens studied by Woodward and now preserved in the collection of the Geological Survey of India (Nos. 9360-68 ; *vide* Woodward 1908, pl. I, fig. 1-6, 9 *b-d*, 10), there are four other specimens (No. K1/316-319) in the collection of that department which are entered in the register as a donation from Rev. S. Hislop. The following further particulars are also noted against each :—

K1/316.	Ganoid scales.	Inter-trappean	. Pahársingha, Nagpur, C. P.
K1/317.	Cycloid scales.	Inter-trappean[1]	. Dongargaon, Nagpur, C. P.
K1/318.	Cycloid scales.	Inter-trappean	. Pahársingha, Nagpur, C. P.
K1/319.	Fish roe.	Inter-trappean	. Tákli, Nagpur, C. P.

[1] Mr. Crookshank informs me that this should be infra-trappean. He wrote to me as follows :—

"As regards the age of the Dongargaon beds we are satisfied that the Inter-trappean in our register should read infra-trappean. All accounts agree that there is only one fossiliferous bed and that infra-trappean. The map shows the same. The disagreement is as to whether this bed should be regarded as infra-trappean of Inter trappean age or as Lameta."

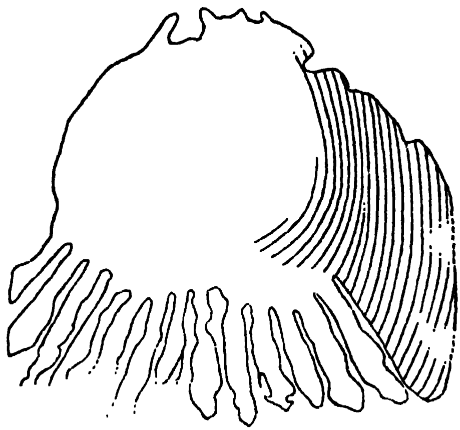
The two Ganoid scales (K1/316; Pl. 18, fig. 2 & 3; text-fig. 13) are of small size and rhombic in outline. Except for their size,



TEXT-FIG. 13.—A Ganoid scale (K1/316) from the Inter-trappean bed at Paharsingha. ×10½.

they agree very closely with the scales of *Lepidosteus indicus* Woodw. (Pl. 18, fig. 4; a loose scale from specimen 9366 of the type series). The Inter-trappean (possibly Lameta) cycloid scale from Dongargaon (K1/317; Pl. 18, fig. 10) belongs to the genus *Clupea*, and is of the type in which the transverse radii are complete. This scale corresponds with similar scales described above from the Inter-trappean beds at Deothan and Kheri. It may here be noted that in the collection of the Geological Survey of India there are two specimens of Clupeoid scales with complete transverse radii (G 152, Pl. 18, fig. 8 & 9; text-fig. 1 *b*) collected from the infra-trappean bed at Dhamni, east of Warora, by F. Fedden in September 1874. This record shows that *Clupea* was found during the infra-trappean period also. The second cycloid scale (K1/318, Pl. 18, fig. 7; text-fig. 14) from Pahársingha appears to be a ctenoid scale of the Percoid type in which the apical teeth are not well preserved or are not exposed. In its minute structure, it bears a close resemblance to the scales of the family Nandidae (*vide supra*, p. 281), a family whose close allies are at the present-day found as far apart as south-eastern Asia, Africa and South America, thereby showing its great antiquity. The fourth specimen of a fish roe (K1/319, Pl. 18,

fig. 1), though of considerable interest from the point of view of its excellent state of preservation, is of little value for the determination of the fish to which it may have belonged.



TEXT-FIG. 14.—A Nandid scale (No. K1/318) from the Inter-trappean bed at Paharsingha. ×30.

As to the fish bone from Tákli with 21 small teeth, it may be safe to presume, on Hislop's testimony, that it probably belonged to the Ganoid *Lepidosteus*.

In view of what is stated above it may now be possible to infer the relative ages of the various beds; but it should be borne in mind that the material is not sufficient to come to any definite conclusion.

Mr. Crookshank tells me that doubts have recently been expressed by Matley on Hislop's determination of the age of the Dongargaon beds, and has given me the following note on this point:

"Hislop states definitely that the Dongargaon fish-remains were found in yellow limestone beneath the Trap. Hughes,[1] who subsequently mapped the area, confirms this, and it is clear from his map that the fossil fish in question were found in beds underlying the Trap, and overlying the Gondwanas.

"Matley[2] re-visited the area in 1919. He admitted that the fish beds underlay Trap, but he could not say whether they rested on Trap, or on older rocks, as he had not seen the base of the beds. It is clear, therefore, that he saw nothing in the field inconsistent with the views of Hislop and Hughes. Nevertheless he concluded that the Dongargaon beds were not Lametas, but were of Inter-trappean age.

[1] *Mem. Geol. Surv. Ind.*, XIII, Pt. I, (1877), pp. 89-90.
[2] *Rec. Geol. Surv. Ind.*, LIII, Pt. 2, (1921), pp. 159-162.

"In making this change he did not rely on the obvious field evidence of the superposition of one set of beds on another. He relied on the lithological dissimilarity of the Dongargaon beds and the Lametas of Jubbulpore, and on the fossil evidence obtained from the Dongargaon beds. These contain fossil fishes said to be early Tertiary, *Bullinus princepii* and a *Melania* similar to those in the Deccan trap Inter-trappeans, and the caudal vertebrae of *Titanosaurus blanfordi* Lyddeker, all of which he considers younger than the Lameta fossil remains of Jubbulpore.

"As the Dongargaon beds were clearly infra-trappean, and were at the same time unlike the true Lametas, and seemed to be younger than them, Matley explained the occurrence as a case of infra-trappean beds of Inter-trappean age. While Matley may be right it is legitimate to point out that no other geologist has found infra-trappean beds of Inter-trappean age, that Saurian bones have never been found in *undoubted* Inter-trappean beds, that *Melania* and *Bullinus* have been found elsewhere extending down into the Cretaceous, and that the lithological evidence is of very little importance. On the whole Hislop's and Hughes' views seem more credible than Matley's, the more so as there is probably a big gap between the end of the Gondwana and the beginning of the Deccan trap period, a gap which is quite wide enough to hold fossil faunas differing as widely as those of the Jubbulpore Lametas and the Dongargaon beds.

"Assuming then that Hislop is right the fossil fish from Dongargaon are probably older than those at Deothan and Kheri. If on the other hand Matley is right they should all be of approximately the same age."

It may be noted, however, that Mr. Crookshank's material was collected on the borders of Hoshangabad and Betul, 100 or more miles distant from Dongargaon, and that it is impossible to correlate the two areas exactly as they are separated by a wide area of unfossiliferous Deccan trap.

Without entering into the geological merits of the controversy concerning the age of the beds at Dongargaon, whether infra- or inter-trappean, it is possible to say from a study of the fish-remains enumerated above that the beds at Dongargaon, associated with a relatively primitive fauna of two Ganoids, *Clupea* and one very primitive Serranid, must be regarded of an earlier age than the Inter-trappean beds at Deothan and Kheri, whence Mr. Crookshank obtained such a great variety of the modern teleostean fish. It is true that Ganoid scales and a piece of bone of the *Lepidosteus*-type have been found in the Inter-trappean beds at Takli and Kateru[1] but the scales are of a relatively much smaller size than those of *L. indicus*, and would thus seem to be of a later period when

[1] Mr. S. R. Narayan Rao discovered the remains of *Lepidosteus* scales from the Inter-trappean bed at Kateru, near Rajamundry, and very kindly allowed me to see and identify the specimen for him. He proposes to publish a separate note on the specimen.

the large deep rivers of the area had presumably been replaced, through the outpouring of lava, by shallow streams.

It may be noted that when large fishes of the type of *Eoserranus*, *Lepidosteus indicus* and *Pycnodus* flourished in the Peninsula (the age of the infra-trappean beds at Dongargaon) the main river of the area may have been like a large deep river, but at the time when the Deothan and Kheri beds were laid down marshy conditions, with lakes of varying sizes in the neighbourhood of the mouth of a large river, had been established. The conditions then were probably similar to those now prevailing in the lower reaches of the Ganges. The presence of a considerable number of Clupeoid scales of fairly large size clearly indicates the deltaic nature of such a river not very far from the beds investigated by Hislop, Fedden, and Crookshank. Clupeoids are mostly marine fishes, but some ascend into large rivers for long distances. The occurrence of the Nandidae, the Pristolepidae, the Polyacanthidae and the Serranidae in the Inter-trappean beds at Deothan and Kheri also indicates the maritime nature of the area, for fishes of these families, even at the present day, are commonly met with in freshwater areas not very far removed from the sea. The typically freshwater Cyprinoids are represented by a single scale of a primitive type, but it will be premature to draw any conclusions from this solitary record, as extensive collections of fish remains, especially of the type dealt with here, have not yet been made.

With regard to the ecological observations made above Mr. Crookshank has very kindly given me the following note from a geological point of view:

"Arguing from the habits of the living fish most closely related to the fossil remains it seems that Deothan and Kheri, where the fossils were found, must have lain on the course of some deep sluggish stream not very far from the sea. The geological evidence on this point is of some interest.

"All geologists who have worked in connection with the Deccan trap have remarked on the extraordinarily low relief of the pre-trappean land surface. Any large river draining this would certainly have been deep and sluggish. The first flows of trap would probably have disturbed such a river but might not have diverted its course greatly. The sediments associated with the fish scales are fine calcareous muds such as one would expect to find in ox-bows or other deep pools associated with large rivers of the present day. The only unusual feature is the presence of volcanic lapilli. Doubtless these were introduced by a shower of volcanic ash immediately preceding the lava flow which buried the pool.

"It is idle to pretend that the details of the drainage and the coastline of western India in pre-trappean times are known, but it is supposed that a great river whose valley is now hidden by the Deccan trap must have flowed westward towards

the Arabian sea somewhere south of the present Narbadda valley. The exact location of such a river is not known, but its upper reaches are probably represented by the Gondwana valleys of the Satpuras and of Wardha district. The lower reaches are entirely hidden by the Deccan trap.

"Marine sedimentaries of late Cretaceous age extend up the Narbadda valley to within 100 miles of Deothan. Nummulitic limestones of Parisian age occur 150 miles further west along the margin of the trap in Broach and Surat. The Deothan fish must have lived at some time between the end of the Cretaceous and the Parisian. It is a reasonable guess, therefore, that there was open sea somewhere between 100 and 250 miles to the west of Deothan in early Deccan trap times.

"The very meagre geological evidence therefore tends to support the conclusions concerning the habitat of the Deothan fossil fishes reached on purely zoological evidence."

In connection with the ecology of the Deothan and Kheri beds attention may be directed to an observation made by Sahni (1934, p. 136) regarding the flora of the Inter-trappean bed at Chhindwara, a place not very far distant from where Crookshank collected his material. In the course of his arguments regarding the Eocene age of these beds he stated:

"One more point seems important although Rode himself does not refer to it. *Nepadites* is not only a genus very characteristic of the eocene period but, unless these palms have changed their mode of life since then, its occurrence in the northern part of the Deccan indicates the existence of an *estuary*, during the early part of the Inter-trappean period in the proximity of Chhindwara. In their valuable memoir on the London Clay flora recently published Reid and Chandler have shown that nearly all the fossil records of *Nipa*-like palms 'lie approximately along the margins of the ancient Nummulitic, or Tethys, sea and its extensions'. So, most probably a north-flowing river debouched into the great Tethys sea or into an arm of that sea, not far to the north of Mr. Rode's home!"

It is thus seen that geological, palaeontological and faunistic evidences all point to the same conclusion, that is, an estuary must have existed in the neighbourhood of the infra- and Inter-trappean beds of the Central Provinces.

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EXPLANATION OF PLATES.

PLATE No. 17.

Inter-trappean Fish Remains.

FIG. 1.—A Pristolepid scale (K29/629). ×20.

FIG. 2.—A Nandid scale (K29/628). ×20.

FIG. 3.—A fragment of a Clupeoid scale (K32/159). ×15.

FIG. 4.—A Labyrinthid scale (K32/147) allied to *Polyacanthus* C. V. ×7.

FIG. 5.—An impression of a Serranid scale (K29/629). ×3.

FIG. 6.—A fragment of a Cyprinoid scale (K32/149). ×7.

FIG. 7.—A fragment of an Osteoglossid scale (K29/631). ×3.

FIG. 8.—Another fragment of an Osteoglossid scale (K29/631). ×3.

PLATE 18.

Inter-trappean Fish Remains.

FIG. 1.—Fish roe (K1/319) from the Inter-trappean of Takli. ×4.

FIG. 2.—Ganoid scale (K1/316), probably of *Lepidosteus*, from the Inter-trappean of Paharsingha. ×4.

FIG. 3.—Another Ganoid scale from Paharsingha. ×5.

FIG. 4.—A scale of *Lepidosteus indicus* Woodw. (No. 9366). ×4.

FIG. 5.—An Acanthopterygian scale (K40/286), Type A. ×20.

FIG. 6.—Fragment of an Acanthopterygian scale (K40/283), Type B. ×4.

FIG. 7.—A Nandid scale (K1/318) from the Inter-trappean of Paharsingha. ×15.

FIG. 8.—Scale of *Clupea* sp. (G 152) from the infra-trappean at Dhamni. ×7.

FIG. 9.—Impression of a scale of *Clupea* sp. (G 152) from the infra-trappean at Dhamni. ×3.

FIG. 10.—Scale of *Clupea* sp. (K1/317) from the infra-trappean of Dongargaon. ×7.

MISCELLANEOUS NOTES.

Tirodite, a manganese amphibole from Tirodi, Central Provinces.

Whilst on a visit to the manganese mines at Tirodi, in the Central Provinces, coarse-bladed prisms of a honey-yellow amphibole were noticed, associated with rather coarse braunite-rock and braunite-spessartite-rhodonite-quartz-rock. The manganese-ore at this point is closely penetrated by granite and pegmatite veins and it was obvious that there had been considerable recrystallisation of the manganese-ore here.

The mineral weathers to a greyish-white colour, almost asbestos like in appearance, and is in strong contrast to the general black colour of the associated ore. However, a fair amount of the unweathered pale yellow translucent mineral was collected.

Macroscopic description.—Colour: pale yellow on the prism direction, deep yellow on the basal parting. Lustre: vitreous. Sp. gr.: 3·312. Hardness: 6½.

Monoclinic; no prism faces were available for measurement. The prismatic cleavage is perfectly developed, the cleavage angle, measured on the goniometer, being 124° 20′. A parting occurs, making an angle with *c* of about 74°, and parallel to *b*.

Optical properties.—The optical characteristics of the mineral are graphically represented in fig. 1. The refractive indices were determined by the immersion method; 2V on the universal stage.

$$\alpha=1{\cdot}629\pm0{\cdot}002.$$
$$\beta=1{\cdot}639-1{\cdot}640\pm0{\cdot}002.$$
$$\gamma=1{\cdot}650\pm0{\cdot}002.$$
$$2V=88^\circ\pm.$$

Plane of the optic axes in the plane of symmetry. $Z \wedge c=21^\circ$, Z in the obtuse angle between *a* and *c*.

Dispersion $\rho > v$

Pleochroism X=pale yellow to colourless.

Y=pale yellow.

Z=pale yellow to straw yellow.

The mineral is often zoned.

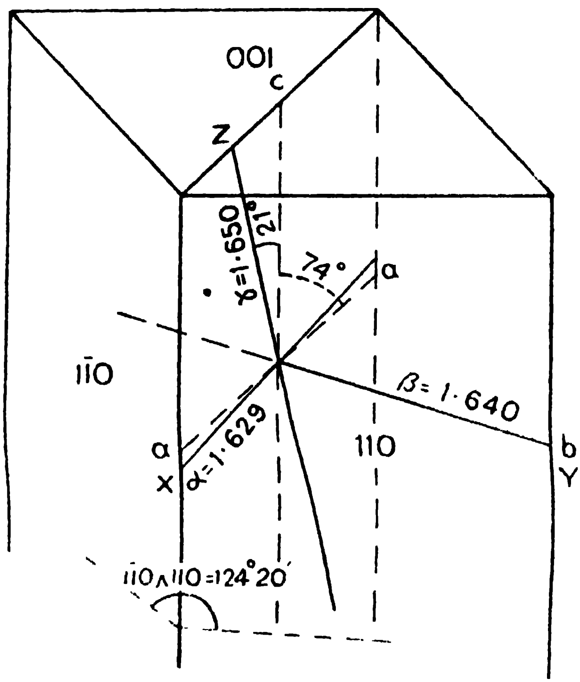


FIG. 1.—Diagram showing the optical characters of tirodite.

Analysis.—For analysis a small, apparently pure, piece was selected and crushed down to$<$0·5 mm. size, then hand-picked under a lens. It was obvious that there were occasional thin films of braunite and quartz along cleavage faces and such fragments as showed contamination were rejected. Fortunately, on crushing, the thin plates of quartz appeared to have separated quite readily from the amphibole. The result of the analysis is shown in Table 1, with also analyses of the nearest known amphiboles, richterite, cummingtonite and dannemorite as quoted by Dana, 'System of Mineralogy'.

The only impurity of any importance in the Tirodi mineral is a little braunite, but, in consequence of the very careful hand-picking, this could not possibly amount to more than 3 per cent., and is almost certainly much less. Allowing for this, the MnO content is still over 5 per cent. The other constituents are definitely in the

tirodite molecule and not mechanically admixed impurities. The mineral is a remarkably pure magnesian-manganese amphibole with

TABLE 1.

—	Tirodite Tirodi.	Richterite.		Cummingtonite Kongsberg.	Dannemorite Dannemora.
		Pajberg.	Langban.		
SiO_2	53·26	52·23	53·28	55·24	48·89
Al_2O_3	1·25	..	2·31	0·18	1·46
Fe_2O_3	2·63	..	..	..	..
FeO	1·06	1·35	1·62	17·63	38·21
MnO	8·25	11·37	7·54	2·00	8·46
MgO	31·26	21·03	19·20	21·17	2·92
CaO	1·11	5·20	8·43	1·85	0·73
K_2O	0·07	8·82 (K_2O + Na_2O)	0·66*	..	..
Na_2O	1·56		6·33	..	..
H_2O	0·05	..	0·71	2·41	..
TOTAL	100·50	100·00	100·08	100·48	100·67

*Li_2O.

Analyst of tirodite—Mr. P. C. Roy.

an unusually high percentage of magnesia. It differs from richterite, cummingtonite and dannemorite in the notably higher percentage of MgO, from cummingtonite and dannemorite in the very low FeO, and from richterite in the low CaO and alkalies.

Fermor [*Memoirs, Geol. Surv. India,* 39, pt. 1, p. 145 (1909)], in noting the occurrence of manganese amphiboles in India, divided them into two divisions according to their colour: bluish amphiboles were classed under winchite; yellow amphiboles, in the absence of more precise determinations, were classed under dannemorite. He regarded them all as of metamorphic origin. Tirodite, if anything, is closer to richterite than to the other amphiboles, but apart from the differences in composition tirodite has slightly higher indices of refraction, 2V, and extinction than the data quoted by Larsen [Bull.

679, *U. S. Geol. Surv.*, p. 257, 1921] for richterite. Tirodite also shows a higher 2V and extinction than for cummingtonite as quoted by Larsen (p. 257).

Tirodite is obviously of metamorphic origin.

J. A. DUNN.

P. C. ROY.

Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma: January to March 1938.

Coal.

——	January.	February.	March.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	20,224	20,961	24,482	65,667
Baluchistan	1,121	886	1,826	3,833
Bengal	615,809	696,194	696,972	2,008,975
Bihar	1,347,906	1,395,377	1,356,809	4,100,092
Orissa	3,617	3,433	3,064	10,114
Central Provinces	161,626	149,514	135,595	446,735
Punjab	16,401	17,129	22,740	56,270
TOTAL	2,166,704	2,283,494	2,241,488	6,691,686

Gold.

——	January.	February.	March.	Quarterly total for each Company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	8,190	7,394	8,191	23,775
The Champion Reef Gold Mines of India Ltd.	5,991	5,440	6,015	17,446
The Ooregum Gold Mining Co. of India Ltd.	4,074	4,070	4,072	12,216
The Nundydroog Mines Ltd	8,844	8,009	8,563	25,416
TOTAL	27,099	24,913	26,841	78,853

Petroleum.

—	Crude Petroleum.	Total gasolene* from natural gas.
	Gallons.	Gallons.
Assam	16,405,712	*Nil.*
Burma	62,872,998	2,459,662
Punjab	4,575,880	118,049
TOTAL .	83,854,590	2,577,711

*These figures represent the total amounts of gasolene derived from natural gas at the well-head. Of these amounts a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries. The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous Records.

A. M. HERON.

Bismuthinite and bismutosphaerite from Manbhum.

(With Plate 19.)

Recently a number of specimens of barytes were submitted to the Geological Survey of India for identification from near Malthole village (23°26′; 86°26′) in Manbhum district. Dr. A. L. Coulson has mentioned the occurrence of barytes at this particular locality in Memoir LXIV, Part I, p. 93 (1933).

Several of the specimens contained galena and bismuthinite. The latter mineral has not previously been recorded from the Indian Peninsula, although bismuth has been recorded by Ball as occurring in traces in the Singhbhum copper ores.

Under the reflecting microscope the bismuthinite is seen to be finely intergrown with galena (Pl. 19, fig. 1). In places cerussite and bismutosphaerite pseudomorphically replace the galena and bismuthinite (Pl. 19, fig. 2). The exact relation between the sulphides and barytes is not clear. The two minerals were identified on the following properties :—

Bismuthinite.—Polishes readily like galena. Hardness: B, less than galena. Reflectivity: about 50, higher than galena. Colour: white, with yellowish tint. Anisotropism: strong, showing yellow, blue, green and grey colours.

Etch tests: Negative—KCN, KOH, $HgCl_2$, $FeCl_3$, HCl.
Positive—HNO_3 with effervescence.

Microchemical tests: Bi and S present. No Pb.

Bismutosphaerite.—Polishes readily. Hardness: B+, a little greater than cerussite. Reflectivity: 8. Colour: grey. Anisotropism: masked by the vivid yellow internal reflection.

Etch tests: Negative—$HgCl_2$, KOH, KCN.
Positive—$FeCl_3$, effervesces with dilute HCl and HNO_3.

Microchemical tests: Bi, no Pb.

EXPLANATION OF PLATE 19.

FIG. 1.—Intergrowth of bismuthinite and galena. Crossed nicols. P. S. 217. ×54.

FIG. 2.—Bismutosphaerite (dark grey) and cerussite (light grey). Unreplaced galena (white). P. S. 217. ×54.

J. A. DUNN.

Apatite and allanite in barytes from Manbhum.

Amongst specimens of barytes from Malthole village, Manbhum district, were several containing crystals of apatite. This association of apatite with barytes is rather interesting, as no such association has been recorded previously, hence this note. The barytes in which the apatite occurs is a fresh white crystalline compact tabular variety. The apatite is sea-green in colour and is either transparent or translucent. The crystals are prismatic, with well developed faces. The specific gravity of the separated crystals is 3·19 and the mean refractive index of the crushed material 1·630±·002. It is a fluor-apatite. Under the microscope the crystals are seen to be often rather crushed. The apatite is fairly abundantly disseminated throughout the barytes and occasional segregations give the specimen a greenish colour in places. Occasionally their linear arrangement gives a banded appearance to

the specimen. The apatite, generally, appears to have crystallised prior to the barytes, but the inclusion of barytes in apatite was noticed in one instance.

It may be interesting to note that the apatite is more abundant where barytes is the only other mineral, and is either scarce or entirely absent where galena is present in large quantities. The association of apatite in barytes would probably throw some light on the origin of the barytes in this particular locality.

In one specimen the barytes contained well formed platy crystals of allanite of a deep brownish red colour, which again is an unusual mineral association.

J. A. DUNN and V. B. RAO.

MGIPC—M—VIII-1-9—11-1-39—800.

FIG. 1. VIEW OF THE ROCKY ARAVALLI QUARTZITE COUNTRY N. E. OF VIRPUR, BALASINOR STATE.

FIG. 2. DECCAN TRAP COUNTRY, SAMOHI, JHABUA.

B. C. Gupta, Photos. *G. S. I., Calcutta.*

FIG. 1. ARAVALLI QUARTZITE (DIP-SLOPE) HADAPH RIVER SECTION, UMRIA, BARIYA STATE.

B. C. Gupta, Photos. *G. S. I., Calcutta.*

FIG. 2. LOW DIPPING ARAVALLI SLATY AND QUARTZITIC BANDS, SOUTH OF MEKHAR, GODHRA.

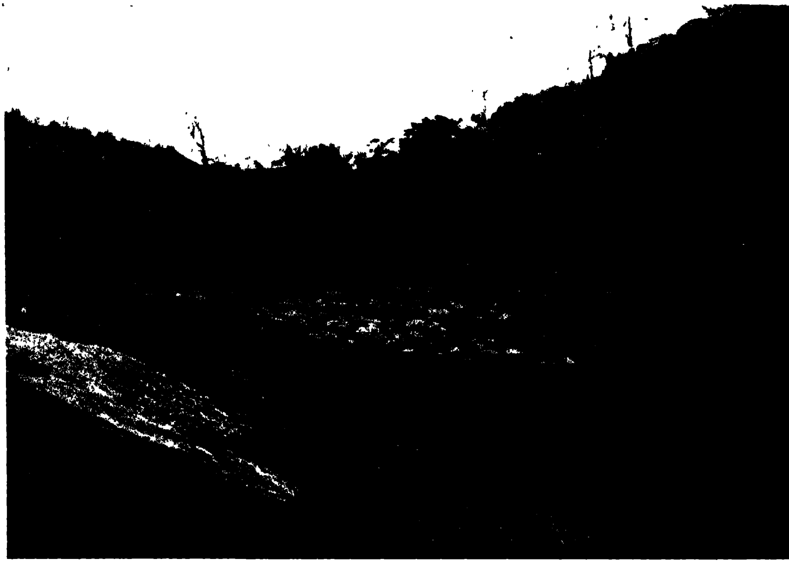
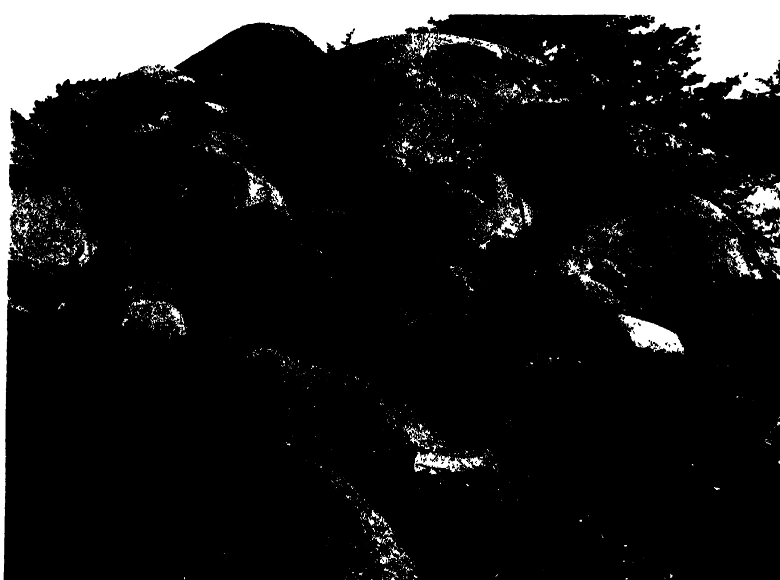


FIG. 1. GENERAL VIEW OF ARAVALLI QUARTZITE RIDGES, UMRIA, BARIYA STATE.



B. C. Gupta, Photos. *G. S. I., Calcutta.*

FIG. 2. WEATHERING OF GRANITE, KOTHAMBA, LUNAVADA STATE.

P N. Mukerji, Photo

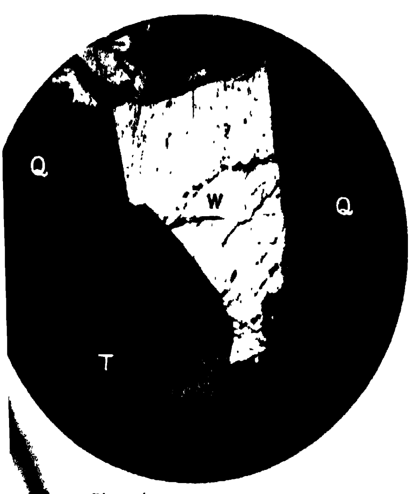
FIG. 1. MANGANESE ORE DEPOSITS INTENSELY FOLDED WITH QUARTZITES AND SHALES, SHIVRAJPUR MINES.

B C. Gupta, Photo *G. S. I., Calcutta.*

FIG. 2. ARAVALLI SCHIST COUNTRY, SOUTH-WEST OF KUNDANPUR, JHABUA STATE.

FIG. 1. CASSITERITE (C) INTERSTITIAL TO WOLFRAM (W). QUARTZ (Q). (× 54).

FIG. 2. CASSITERITE (C) AND MOLYBDENITE (M) INTERSTITIAL TO WOLFRAM (W). BAKELITE (B). CROSSED NICOLS. (× 54).



...unn, *Photomicros.*

G. S. I., Calcutta.

...G. 3. WOLFRAM (W) PARTLY ENCLOSING A TOURMALINE CRYSTAL (T) IN QUARTZ (Q). (× 54).

FIG. 4. SCHEELITE (DARK GREY) REPLACING WOLFRAM (LIGHT GREY). (× 54).

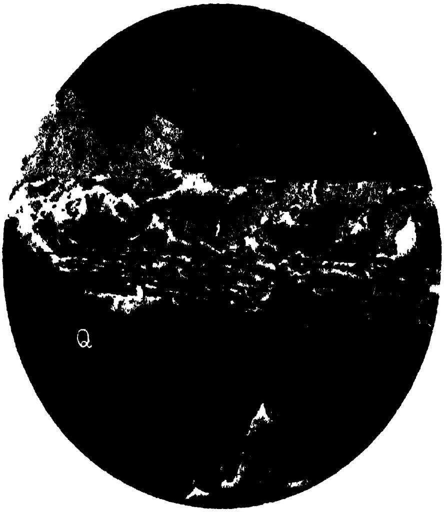


FIG. 1. WOLFRAM CRYSTAL (W) REPLACED BY SCHEELITE (S). CASSITERITE (C) AND QUARTZ (Q). BAKELITE (B). (× 28).

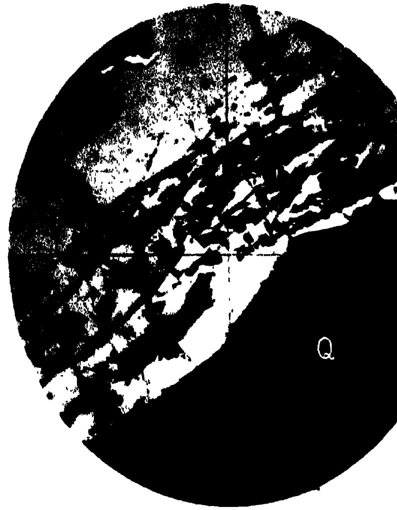


FIG. 2. QUARTZ (DARK GREY) REPLACING WOLFRAM (LIGHT GREY). A LITTLE PYRITE (WHITE). (× 54).

J. A. Dunn, Photomicros.

G. S. I., Calcutt

FIG. 3. PYRITE VEINLETS IN QUARTZ (Q) AND WOLFRAM (W). (× 54).

FIG. 4. PYRITE (P) VEINING TOURMALINE (T) AND BOTH REPLACED AND VEINED BY CHLORITE (C). (× 54).

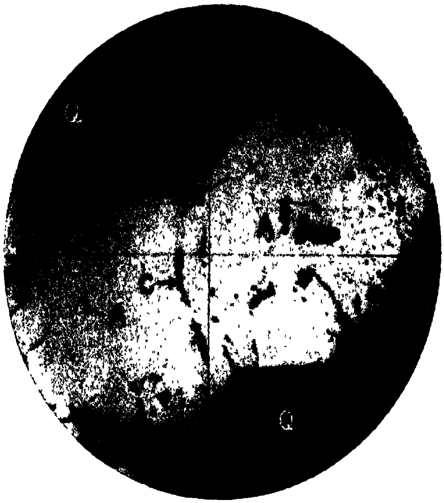
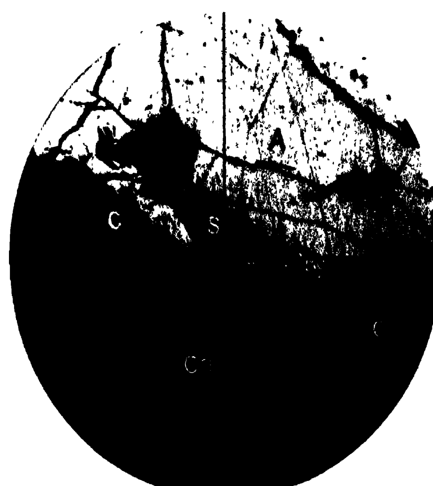


FIG. 1. PYRITE (P) AND CHALCOPYRITE (C) VEINING ARSENOPYRITE (A). QUARTZ (Q). (× 28).

FIG. 2. ARSENOPYRITE (WHITE) VEINED BY CHALCOPYRITE (GREY) AND CARBONATE (BLACK). (× 180).



J. A. Dunn, Photomicros.

G. S. I., Calcutta.

FIG. 3. ARSENOPYRITE NEEDLES IN CHLORITE (DARK GREY); THE LATTER REPLACES QUARTZ (LIGHTER GREY) AND GALENA (WHITE). PYRITE (P). (× 54).

FIG. 4. SPHALERITE (S) VEINING AND REPLACING ARSENOPYRITE (A). ALSO CHALCOPYRITE (C) AND CARBONATE (Ca). (× 84).

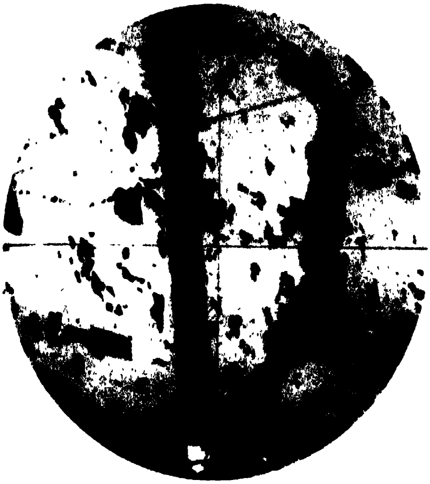


FIG. 1. QUARTZ VEINS IN SPHALERITE. (× 40).

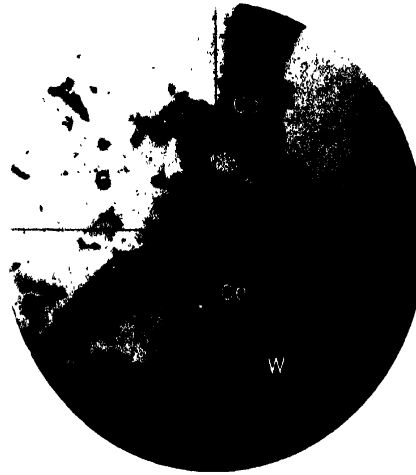
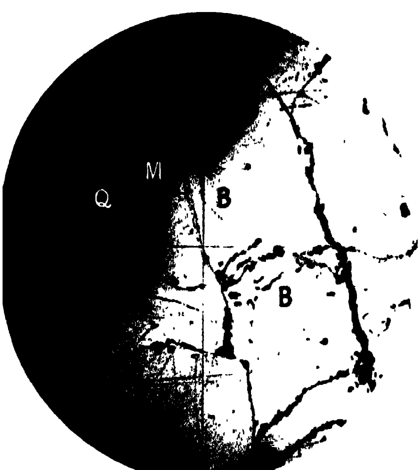
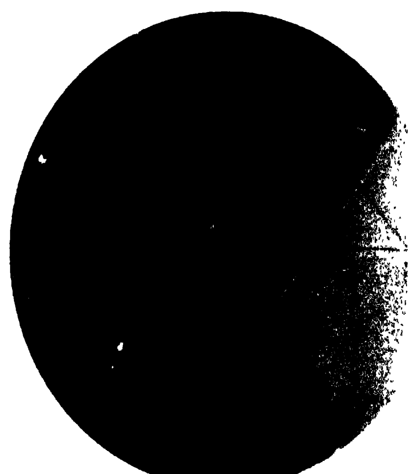


FIG. 2. STANNITE (S) AND GALENA (G) WHICH VEINED STANNITE BUT IS ALTERED IN PART TO CERUSSITE (Ce). WOLFRAM (W). OIL IMMERSION. (× 420).





J. A. Dunn, Photomicros. *G. S. I., Calcutta.*

FIG. 3. MOLYBDENITE FLAKE (M) IN BISMUTHINITE (B) AND QUARTZ (Q), THE BISMUTHINITE REPLACING THE QUARTZ ALONG THE MOLYBDENITE. NOTE THE STRONG DIFFERENCE IN REFLECTIVITY BETWEEN ADJACENT AREAS OF BISMUTHINITE. (× 54).

FIG. 4. INTERGROWTH OF BISMUTHINITE IN GALENA. CROSSED NICOLS. (× 54).

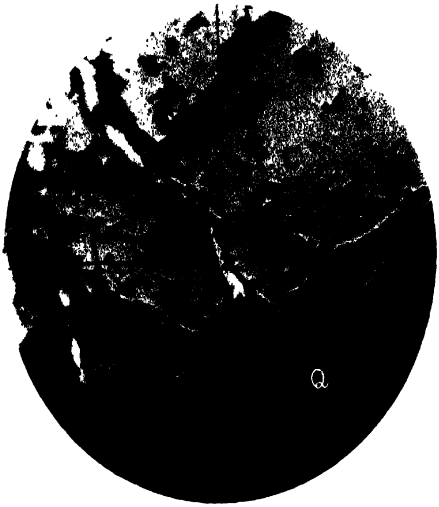


FIG. 1. GALENA VEIN (WHITE) IN CASSITERITE (C). QUARTZ (Q). (× 180).

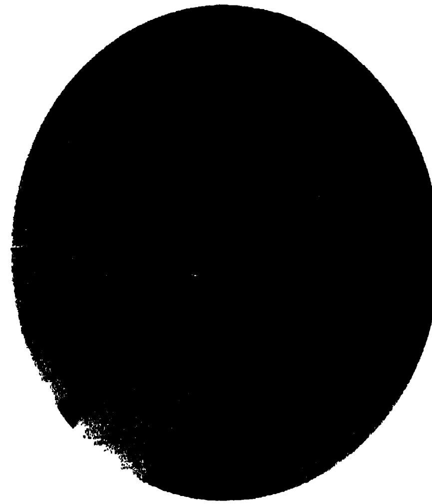
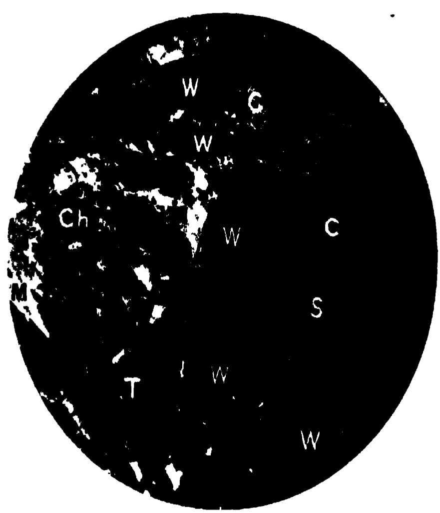


FIG. 2. CHALCOPYRITE (C) PARTLY ALTERED TO CHALCOCITE AND COVELLITE, AND STANNITE (S) VEIN ALONG CLEAVAGE IN GALENA. (× 235).



A. Dunn, Photomicros.

G. S. I., Calcutta.

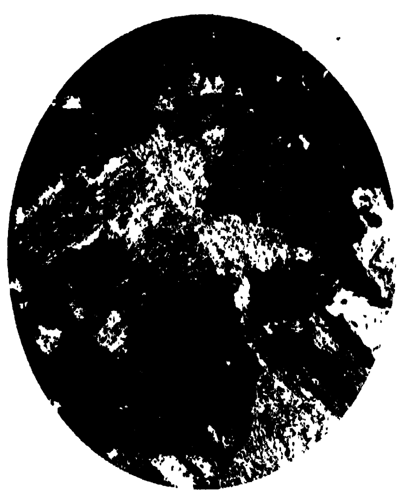
FIG. 3. ZONING IN CASSITERITE (THIN SECTION). (× 24).

FIG. 4. TOURMALINE (T) REPLACED BY MUSCOVITE (M) AND CHLORITE (Ch) IN CASSITERITE (C) AND WOLFRAM (W). (× 24).

Records, Vol. 73, Pl. 11.

FIG. 1. CASSITERITE REPLACED BY INTERSTITIAL FELSPAR. (× 24).

FIG. 2. CASSITERITE REPLACED AND VEINED BY BERYL. (× 24).



A. Dunn, Photomicros.

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FIG. 3. BERYL REPLACED ALONG ITS CLEAVAGE, AT WALLS OF SCHEELITE VEIN. (× 24).

FIG. 4. SCHEELITE REPLACING PLATY CARBONATE. (× 24).

FIG. 1. MICA VEINS (M) IN CASSITERITE (C). NOTE HOW ONE OF THEM STOPS AT THE BORDER OF SCHEELITE (S) AFTER WOLFRAM, AND ITS POSITION IN THE LATTER OCCUPIED BY CLEAR SCHEELITE. TOURMALINE (T). (× 24).

FIG. 2. TOURMALINE (T) AND CASSITERITE (C) VEINED BY LEPIDOLITE (M). (× 24).

A. Dunn, Photomicr.

FIG. 3. RELIC QUARTZ IN PLATY CARBONATE. (× 24).

G. S. I., Calcutta.

FIG. 4. PLATY CARBONATE. (× 24).

Records, Vol. 73, Pl. 13.

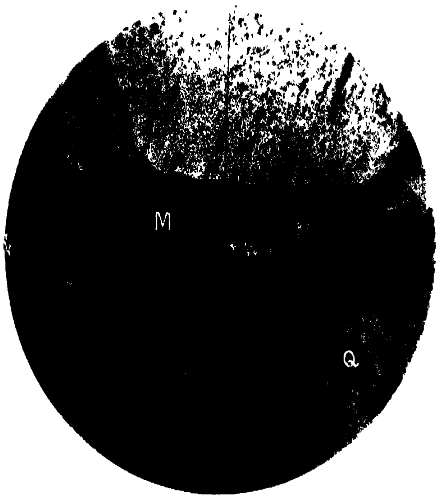


FIG. 1. WOLFRAM VEINING MUSCOVITE (M) WHICH APPEARS ALSO TO BE INTERSTITIAL TO COARSER WOLFRAM (W). QUARTZ (Q). (× 54).

FIG. 2. WOLFRAM (LIGHT GREY) BRECCIATED AND VEINED BY QUARTZ (DARK GREY) (× 54).

J. A Dunn, Photomicros.

FIG. 3. CASSITERITE (DARK GREY) REPLACED BY WOLFRAM (GREY). QUARTZ VEIN TO LEFT. (× 54).

G. S. I., Calcutta.

FIG. 4. CASSITERITE (WHITE) VEINED AND REPLACED BY QUARTZ (GREY). (× 54).

Records, Vol. 73, Pl. 14.

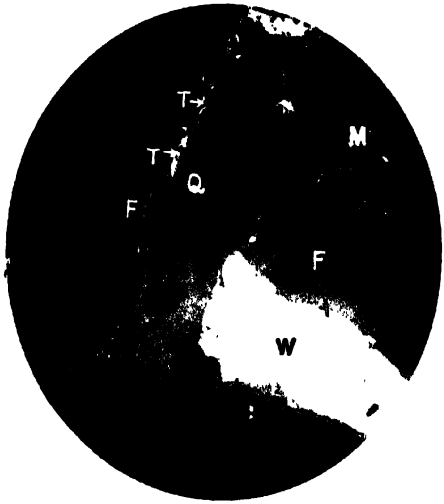
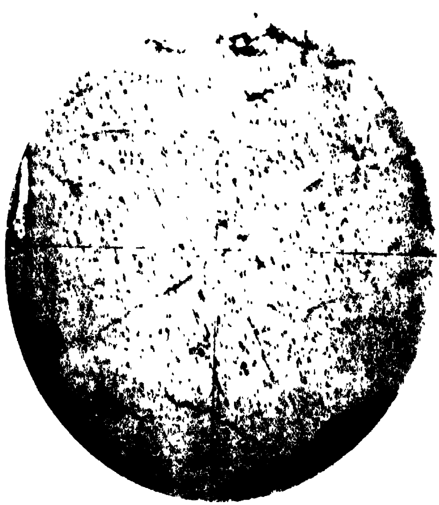
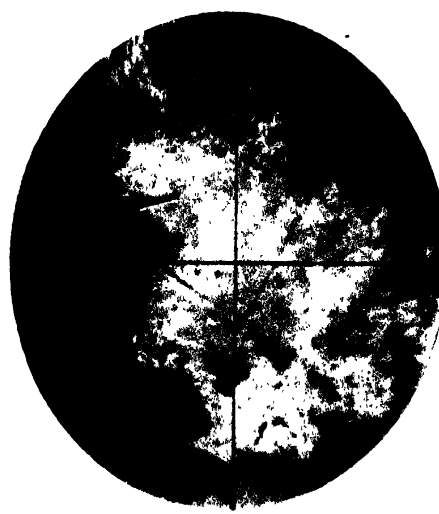


FIG. 1. FLUORITE (F) REPLACING QUARTZ (Q). WOLFRAM (W) AND TUNGSTITE (T). CRACKS IN FLUORITE, INFILLED WITH BAKELITE, APPEAR LIKE QUARTZ. (× 54).
M = Muscovite.

FIG. 2. PYRITE (P) REPLACED BY SPHALERITE (S), IN TURN VEINED BY CHALCOPYRITE (C) AND GALENA (G). (× 54).
Q = Quartz.





J. A. Dunn, Photomicros.

G. S. I., Calcutta.

FIG. 3. VEINS OF GALENA AND BISMUTHINITE (WHITE) IN WOLFRAM. (× 54).

FIG. 4. EX-SOLUTION DROPLETS OF BISMUTH IN BISMUTHINITE. OIL IMMERSION. (× 540).

Records, Vol. 73, Pl. 15.

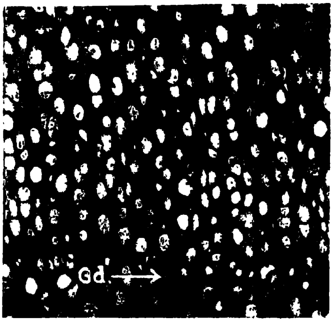


FIG. 1. (× 10).

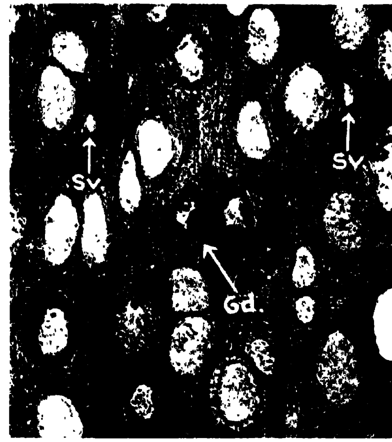


FIG. 2. (× 40).

FIG. 3. (× 75).

FIG. 4. (× 35).

FIG. 5. (× 50).

FIG. 6. (× 110).

K. A. Chowdhury, Photos.

G. S. I., Calcutta.

DIPTEROCARPOXYLON GAROENSE, *sp. nov.*

FIG. 1. (× 90).

FIG. 2. (× 440).

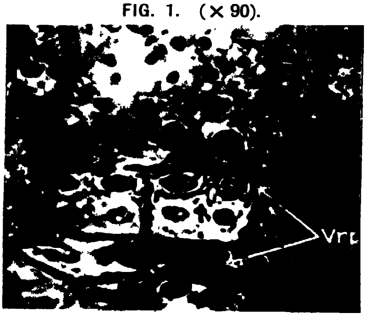


FIG. 3. (× 400).

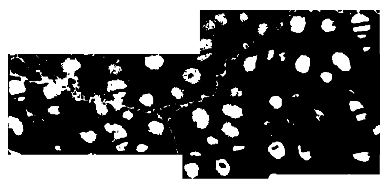


FIG. 4. (× 10).

FIG. 5. (× 75).

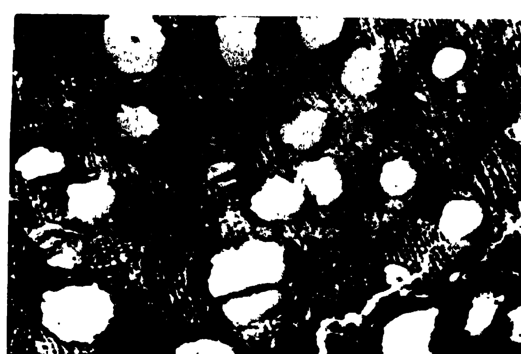


FIG. 6. (× 35).

K. A. Chowdhury, Photos. *G. S. I., Calcutta.*

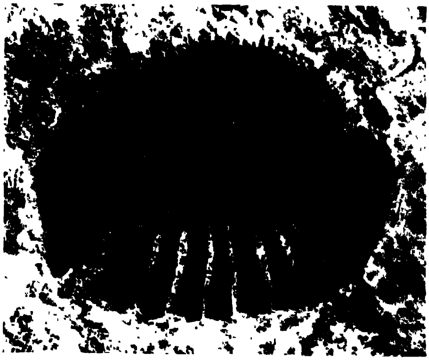
DIPTEROCARPOXYLON GAROENSE, *Sp. nov.*

FIGS. 1, 2, 3.

DRYOXYLON, *Sp.*

FIGS. 4, 5, 6.

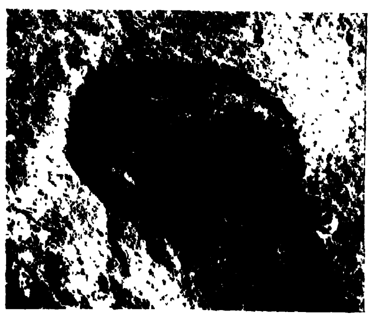
Records, Vol. 73, Pl. 17.



1. (× 20).

2. (× 20).

3. (× 15).



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S. C. Mondul, Photos.

G. S. I., Calcutta.

INTER-TRAPPEAN FISH REMAINS.

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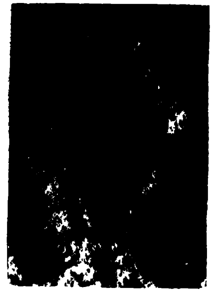

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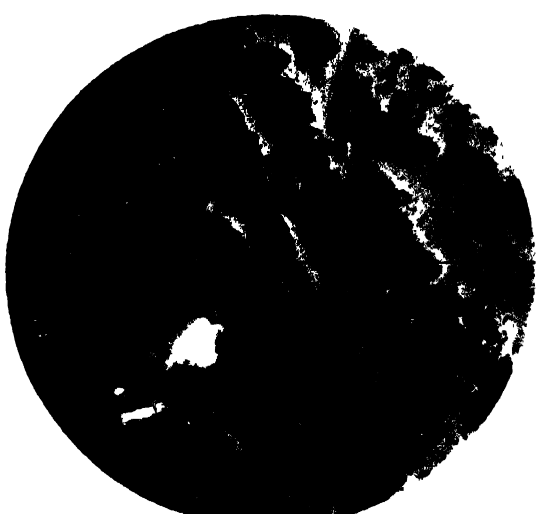
S. C. Mondul, Photos.

G. S. I., Calcutta.

INTER-TRAPPEAN FISH REMAINS.

FIG. 1. INTERGROWTH OF BISMUTHINITE AND GALENA. CROSSED NICOLS.



J. A. Dunn, Photomicros. *G. S. I., Calcutta.*

FIG. 2. BISMUTOSPHAERITE (DARK GREY) AND CERUSSITE (LIGHT GREY). UNREPLACED GALENA (WHITE).

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA.

VOL. I, 1868.

Part 1 (out of print).—Annual report for 1867. Coal-seams of Tawa valley. Coal in Garrow Hills. Copper in Bundelkhund. Meteorites.

Part 2 (out of print).—Coal-seams of neighbourhood of Chanda. Coal near Nagpur. Geological notes on Surat collectorate. Cephalopodous fauna of South Indian cretaceous deposits. Lead in Raipur district. Coal in Eastern Hemisphere. Meteorites.

Part 3 (out of print).—Gastropodous fauna of South Indian cretaceous deposits. Notes on route from Poona to Nagpur *viâ* Ahmednuggur, Jalna, Loonar, Yeotmahal, Mangali and Hingunghat. Agaté-flake in pliocene (?) deposits of Upper Godavary. Boundary of Vindhyan series in Rajputana. Meteorites.

VOL. II, 1869.

Part 1 (out of print).—Valley of Poorna river, West Berar. Kuddapah and Kurnool formations. Geological sketch of Shillong plateau. Gold in Singhbhum, etc. Wells at Hazareebagh. Meteorites.

Part 2 (out of print).—Annual report for 1868. Pangshura tecta and other species of Chelonia from newer tertiary deposits of Nerbudda valley. Metamorphic rocks of Bengal.

Part 3 (out of print).—Geology of Kutch, Western India. Geology and physical geography of Nicobar Islands.

Part 4 (out of print).—Beds containing silicified wood in Eastern Prome, British Burma. Mineralogical statistics of Kumaon division. Coal-field near Chanda. Lead in Raipur district. Meteorites.

VOL. III, 1870.

Part 1 (out of print).—Annual report for 1869. Geology of neighbourhood of Madras. Alluvial deposits of Irrawadi, contrasted with those of Ganges.

Part 2 (out of print).—Geology of Gwalior and vicinity. Slates at Chiteli, Kumaon. Lead vein near Chicholi, Raipur district. Wardha river coal-fields, Berar and Central Provinces. Coal at Karba in Bilaspur district.

Part 3 (out of print).—Mohpani coal-field. Lead-ore at Slimanabad, Jabalpur district. Coal, east of Chhattisgarh between Bilaspur and Ranchi. Petroleum in Burma. Petroleum locality of Sudkal, near Futtijung, west of Rawalpindi. Argentiferous galena and copper in Manbhum. Assays of iron ores.

Part 4 (out of print).—Geology of Mount Tilla, Punjab. Copper deposits of Dalbhum and Singhbhum: 1.—Copper mines of Singhbhum: 2.—Copper of Dalbhum and Singhbhum. Meteorites.

VOL. IV, 1871.

Part 1 (out of print).—Annual report for 1870. Alleged discovery of coal near Gooty, and of indications of coal in Cuddapah district. Mineral statistics of Kumaon division.

Part 2 (out of print).—Axial group in Western Prome. Geological structure of Southern Konkan. Supposed occurrence of native antimony in the Straits Settlements. Deposit in boilers of steam-engines at Raniganj. Plant-bearing sandstones of Godavari valley, on southern extensions of Kamthi group to neighbourhood of Ellore and Rajmandri, and on possible occurrence of coal in same direction.

Part 3 (out of print).—Borings for coal in Godavari valley near Dumagudem and Bhadrachalam. Narbada coal-basin. Geology of Central Provinces. Plant-bearing sandstones of Godavari valley.

Part 4 (out of print).—Ammonite fauna of Kutch. Raipur and Hengir (Gangpur) Coal-field. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Vol. V, 1872.

Part 1 (out of print).—Annual report for 1871. Relations of rocks near Murree (Mari), Punjab. Mineralogical notes on gneiss of South Mirzapur and adjoining country. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Part 2 (out of print).—Coasts of Baluchistan and Persia from Karachi to head of Persian Gulf, and some of Gulf Islands. Parts of Kummummet and Hanamconda districts in Nizam's Dominions. Geology of Orissa. New coal-field in south-eastern Hyderabad (Deccan) territory.

Part 3 (out of print).—Maskat and Massandim on east of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.

Part 4 (out of print).—Coal in northern region of Satpura basin. Evidence afforded by raised oyster banks on coasts of India, in estimating amount of elevation indicated thereby. Possible field of coal-measures in Godavari district, Madras Presidency. Lameta or intra-trappean formation of Central India. Petroleum localities in Pegu. Supposed eozoonal limestone of Yellam Bile.

Vol. VI, 1873.

Part 1.—Annual report for 1872. Geology of North-West Provinces.

Part 2 (out of print).—Bisrampur coal-field. Mineralogical notes on gneiss of south Mirzapur and adjoining country.

Part 3 (out of print).—Celt in ossiferous deposits of Narbada valley (Pliocene of Falconer): on age of deposits, and on associated shells. Barakars (coal-measures) in Beddadanole field, Godavari district. Geology of parts of Upper Punjab. Coal in India. Salt-springs of Pegu.

Part 4 (out of print).—Iron deposits of Chanda (Central Provinces). Barren Islands and Narkondam. Metalliferous resources of British Burma.

Vol. VII, 1874.

Part 1 (out of print).—Annual report for 1873. Hill ranges between Indus valley in Ladak and Shah-i-Dula on frontier of Yarkand territory. Iron ores of Kumaon. Raw materials for iron-smelting in Raniganj field. Elastic sandstone, or so-called Itacolumyte. Geological notes on part of Northern Hazaribagh.

Part 2 (out of print).—Geological notes on route traversed by Yarkand Embassy from Shah-i-Dula to Yarkand and Kashgar. Jade in Karakash valley, Turkistan. Notes from Eastern Himalaya. Petroleum in Assam. Coal in Garo Hills. Copper in Narbada valley. Potash-salt from East India. Geology of neighbourhood of Mari hill station in Punjab.

Part 3 (out of print).—Geological observations made on a visit to Chadderkul, Thian Shan range. Former extension of glaciers within Kangra district. Building and ornamental stones of India. Materials for iron manufacture in Raniganj coal-field. Manganese-ore in Wardha coal-field.

Part 4 (out of print).—Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

Vol. VIII, 1875.

Part 1 (out of print).—Annual report for 1874. The Altum-Artush considered from geological point of view. Evidences of 'ground-ice' in tropical India, during Talchir period. Trials of Raniganj fire-bricks.

Part 2 (out of print).—Gold-fields of south-east Wynaad, Madras Presidency. Geological notes on Khareean hills in Upper Punjab. Water-bearing strata of Surat district. Geology of Scindia's territories.

Part 3 (out of print).—Shahpur coal-field, with notice of coal explorations in Narbada regions. Coal recently found near Moflong, Khasia Hills.

Part 4 (out of print).—Geology of Nepal. Raigarh and Hingir coal-fields.

Vol. IX, 1876.

Part 1 (out of print).—Annual report for 1875. Geology of Sind.

Part 2 (out of print).—Retirement of Dr. Oldham. Age of some fossil floras of India. Cranium of Stegodon Ganesa, with notes on sub-genus and allied forms. Sub-Himalayan series in Jamu (Jammoo) Hills.

Part 3 (*out of print*).—Fossil floras in India. Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Malori and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.

Part 4 (*out of print*).—Fossil floras in India. Osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

VOL. X, 1877.

Part 1 (*out of print*).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheria in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Embydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (*out of print*).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (*out of print*).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (*out of print*).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis', McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

VOL. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (*out of print*).—Geology of Sind (second notice). Origin of Kumaon lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

Part 3 (*out of print*).—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

VOL. XII, 1879.

Part 1 (*out of print*).—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammals. Siwalik beds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2 (*out of print*).—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kuram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3 (*out of print*).—Geological features of northern Madura, Padukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia speciosa, Royle (Sphenophyllum trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbudda.

Part 4.—"Attock Slates" and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1 (*out of print*).—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of North-Eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas'. Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain: and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danaite from Khetri mines, Rajputana; with remarks on Jaipurite (Syepoorite). Zinc-ore (Smithsonite and Blende) with barytes in Karnul district, Madras. Mud-eruption in island of Cheduba.

Part 3 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Unification of geological nomenclature and cartography. Geology of Arvali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah district, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district; (2) arsenical pyrites in same neighbourhood; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field. Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Gold-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kayn (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosalpore, Jabalpur district. Umaria coal-field.

Part 3 (out of print).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussoorree. Cretaceous coal-measures at Borsora in Khasia Hills, near Laour in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

VOL. XVII, 1884.

Part 1 (out of print).—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Kurnool district. Geology of Chuari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (out of print).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (out of print).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishâpûr, Khorassan. Fiery eruption from Mynbyin mud volcano of Cheduba Island, Arakan. Langrin coal-field, South-West Khasia Hills. Umaria coal-field.

Part 4 (out of print).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

VOL. XVIII, 1885.

Part 1 (out of print).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2 (out of print).—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (out of print).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthalla and Chandpur meteorites. Oil wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmein district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (out of print).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

VOL. XIX, 1886.

Part 1 (out of print).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field notes. Section from Simla to Wangtu, and petrological character of Amphibolites and Quartz-Diorites of Sutlej valley.

Part 2 (out of print).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruptive rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-note from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2 (out of print).—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west, of Salt-range, in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Woolasten Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-fields, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part I.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicyonodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive-group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal fields of Lairungao, Meosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1 (out of print).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-spring near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (out of print).—Mammalian Bones from Mongolia. Darjiling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1 (out of print).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dasht-i-Bedaolt; with appendices on Chammans of Quetta; and Artesian water supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Saféd Kôh. Jherria Coal-field.

Part 3 (out of print).—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (out of print).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Ambar-like Resin in Burma. Triassic Deposits of Salt-range.

Vol. XXVI, 1893.

Part 1 (out of print).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma. Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2 (out of print).—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (out of print).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4 (out of print).—Geology of country between Chappar Rift and Harnai in Baluchistan. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

Vol. XXVII, 1894.

Part 1 (out of print).—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.
Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.
Part 3 (out of print).—Cambrian Formation of Eastern Salt-range. Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.
Part 4 (out of print).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistan. Highly Phosphatic Mica Periodotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Periodotite in Bengal.

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.
Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.
Part 3 (out of print).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.
Part 4 (out of print).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyans. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

Vol. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.
Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwana-land". Notes.
Part 3.—Igneous Rocks from the Tochi Valley. Notes.
Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

Vol. XXX, 1897.

Part 1 (out of print).—Annual report for 1896. Norite and associated Basic Dykes and Lava flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.
Part 2.—Cretaceous Deposits of Pondicherri. Notes.
Part 3 (out of print).—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikaner. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.
Part 4 (out of print).—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Caut. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

Vol. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjiling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.
Part 2 (out of print).—Lt.-Genl. C. A. MacMahon. Cyclobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.
Part 3 (out of print).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.
Part 4 (out of print).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

Vol. XXXII, 1905.

Part 1.—Review of Mineral Production of India during 1898-1903.

Part 2 (out of print).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and U in Tibet. Bauxite in India. Miscellaneous Notes.

Part 3 (out of print).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites-Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.

Part 4.—Obituary notices of H. B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

Vol. XXXIII, 1906.

Part 1 (out of print).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.

Part 2 (out of print).—General report for 1905. Lashio Coal field, Northern Shan States. Namma, Mansang and Man-se-le Coal-fields, Northern Shan States, Burma. Miscellaneous Notes.

Part 3 (out of print).—Petrology and Manganese-ore Deposits of Sausar Tahsil, Chhindwara district, Central Provinces. Geology of part of valley of Kanhan River in Nagpur and Chhindwara districts, Central Provinces. Manganite from Sandur Hills. Miscellaneous Notes.

Part 4 (out of print).—Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond bearing Deposits. Index to Volume XXXIII.

Vol. XXXIV, 1906.

Part 1 (out of print).—Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan. Coal Occurrences in Foot-hills of Bhutan. Dandli Coal-field: Coal outcrops in Kotli Tahsil of Jammu State. Miscellaneous Notes.

Part 2 (out of print).—Mineral production of India during 1905. Nummulites Douvillei, with remarks on Zonal Distribution of Indian Nummulites. Auriferous Tracts in Southern India. Abandonment of Collieries at Warora, Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Explosion Craters in Lower Chindwin District, Burma. Laterites of Pavagad Hill. Gibbsite with Manganese-ore from Talevadi, Belgaum district, and Gibbsite from Bhekowli, Satara District. Classification of Tertiary System in Sind with reference to Zonal Distribution of Eocene Echinoidea.

Part 4 (out of print).—Jaipur and Nazira Coal-fields, Upper Assam. Makum Coal-fields between Tirap and Namdang Streams. Kobat Anticline, near Seiktein, Myingyan district, Upper Burma. Asymmetry of Yenangyat-Singu Anticline, Upper Burma. Northern part of Gwegyo Anticline, Myingyan District, Upper Burma. Breynia Multituberculata, from Nari of Baluchistan and Sind. Index to Volume XXXIV.

Vol. XXXV, 1907.

Part 1 (out of print).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokachi and neighbourhood, Dacca district.

Part 2 (out of print).—Indian Aerolites. Brine-wells at Bawgyo, Northern Shan States. Gold-bearing Deposits of Loi Twang, Shan States. Physa Prinsepii in Maestrichtian strata of Baluchistan. Miscellaneous Notes.

Part 3.—Preliminary survey of certain Glaciers in North-West Himalaya. A.—Notes on certain Glaciers in North-West Kashmir.

Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

Vol. XXXVI, 1907-08.

Part 1 (out of print).—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic outburst of Late Tertiary Age in South Hsenwi, N. Shan States. New suidæ from Bugti Hills, Baluchistan. Permo-Carboniferous Plants from Kashmir.

Part 2 (out of print).—Mineral Production of India during 1906. Ammonites of Bagh Beds. Miscellaneous Notes.

Part 3 (out of print).—Marine fossils in Yenangyaung oil-field, Upper Burma. Freshwater shells of genus Batissa in Yenangyaung oil-field, Upper Burma. New Species of Dendrophyllia from Upper Miocene of Burma. Structure and age of Taungtha hills, Myingyan district, Upper Burma. Fossils from Sedimentary rocks of Oman (Arabia). Rubies in Kachin hills, Upper Burma. Cretaceous Orbitoides of India. Two Calcutta Earthquakes of 1906. Miscellaneous Notes.

Part 4 (out of print).—Pseudo-Fucoids from Pab sandstones at Fort Munro, and from Vindhyan series. Jadeite in Kachin Hills, Upper Burma. Wetchok-Yedwet Pegu outcrop, Magwe district, Upper Burma. Group of Manganates, comprising Hollandite, Psilomelane and Coronadite. Occurrence of Wolfram in Nagpur district, Central Provinces. Miscellaneous Notes. Index to Volume XXXVI.

Vol. XXXVII, 1908-09.

Part 1 (out of print).—General report for 1907. Mineral Production of India during 1907. Occurrence of striated boulders in Blaini formation of Simla. Miscellaneous Notes.

Part 2 (out of print).—Tertiary and Post-Tertiary Freshwater Deposits of Baluchistan and Sind. Geology and Mineral Resources of Rajpipla State. Suitability of sands in Rajmahal Hills for glass manufacture. Three new Manganese-bearing minerals:—Vredenburgite, Sitaparite and Juddite. Laterites from Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Southern part of Gwegyo Hills, including Payagyigon-Ngashandaung Oil-field. Silver-lead mines of Bawdwin, Northern Shan States. Mud volcanoes of Arakan Coast, Burma.

Part 4.—Gypsum Deposits in Hamirpur district, United Provinces. Gondwanas and related marine sedimentary system of Kashmir. Miscellaneous Notes. Index to Volume XXXVII.

Vol. XXXVIII, 1909-10.

Part 1.—General report for 1908. Mineral Production of India during 1908.

Part 2 (out of print).—Ostrea latimarginata in "Yenangyaung stage" of Burma. China-clay and Fire-clay deposits in Rajmahal Hills. Coal at Gilhurria in Rajmahal hills. Pegu Inlier at Ondwe, Magwe district, Upper Burma. Salt Deposits of Rajputana. Miscellaneous Notes.

Part 3.—Geology of Sarawan, Jhalawan, Mekran and the State of Las Bela. Hippurite-bearing Limestone in Seistan and Geology of adjoining region. Fusulinidæ from Afghanistan. Miscellaneous Notes.

Part 4.—Geology and Prospects of Oil in Western Prome and Kama, Lower Burma (including Namayan, Padaung, Taungbogyi and Ziaing). Recorrelation of Pegu system in Burma with notes on Horizon of Oil-bearing Strata (including Geology of Padaukpin, Banbyin and Aukmanein). Fossil Fish Teeth from Pegu system, Burma. Northern part of Yenangyat Oil-field. Iron Ores of Chanda, Central Provinces. Geology of Aden Hinterland. Petrological Notes on rocks near Aden. Upper Jurassic Fossils near Aden. Miscellaneous Notes. Index to Volume XXXVIII.

Vol. XXXIX, 1910.

Quinquennial Review of Mineral Production of India during 1904 to 1908 (*out of print*).

Vol. XL, 1910.

Part 1.—Pre-Carboniferous Life-Provinces. Lakes of Salt Range in the Punjab. Preliminary survey of certain Glaciers in Himalaya. D.—Notes on certain Glaciers in Sikkim. New Mammalian Genera and Species from Tertiaries of India.

Part 2 (out of print).—General Report for 1909. Mineral Production of India during 1909.

Part 3.—Revised Classification of Tertiary Freshwater Deposits of India. Revision of Silurian-Trias Sequence in Kashmir. Fenestella-bearing beds in Kashmir.

Part 4 (out of print).—Alum Shale and Alum Manufacture, Kalabagh, Mianwali district, Punjab. Coal-fields in North-Eastern Assam. Sedimentary Deposition of Oil. Miscellaneous Notes. Index to Volume XL.

Vol. XLI, 1911-12.

Part 1.—Age and continuation in Depth of Manganese-ores of Nagpur-Balaghat Area, Central Provinces. Manganese-ore deposits of Gangpur State, Bengal, and Distribution of Gondite Series in India. Baluchistan Earthquake of 21st October 1909. Identity of Ostrea Promensis, Noetling, from Pegu System of Burma and Ostrea Digitalina, Eichwald, from Miocene of Europe. Mr. T. R. Blyth. Miscellaneous Notes.

Part 2.—General Report for 1910. Devonian Fossils from Chitral, Persia, Afghanistan and Himalayas. Sections in Pir Panjal Range and Sind Valley Kashmir.

Part 3.—Mineral Production of India during 1910. Samarskite and other minerals in Nellore District, Madras Presidency. Coal in Namchik Valley, Upper Assam. Miscellaneous Notes.

Part 4.—Pegu-Eocene Succession in Minbu District near Ngape. Geology of Henzada District, Burma. Geology of Lonar Lake, with note on Lonar Soda Deposit. International Geological Congress of Stockholm. Miscellaneous Notes. Index to Volume XLI.

VOL. XLII, 1912.

Part 1.—Survival of Miocene Oyster in Recent Seas. Silurian Fossils from Kashmir. Blödite from Salt Range. Gold-bearing Deposits of Mong Long, Hsipaw State, Northern Shan States, Burma. Steatite Deposits, Idar State. Miscellaneous Notes.

Part 2.—General Report for 1911. Dicotyledonous Leaves from Coal Measures of Assam. Poting Glacier, Kumaon, Himalaya, June 1911. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1911. Kodurite Series.

Part 4.—Geological Reconnaissance through Dehong Valley, being Geological Results of Abor Expedition, 1911-12. Traverse across the Naga Hills of Assam. Indian Aerolites. Miscellaneous Notes.

VOL. XLIII, 1913.

Part 1 (out of print).—General Report for 1912. Garnet as a Geological Barometer. Wolframite in Tavoy District, Lower Burma. Miscellaneous Notes.

Part 2 (out of print).—Mineral Production of India during 1912. Relationship of the Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Hambergite from Kashmir.

Part 3.—Contributions to the geology of the Province of Yünnan in Western China: I.—Bhamo-Têng-Yueh Area. II.—Petrology of Volcanic Rocks of Têng-Yueh District. The Kirna Hills. Banswal Aerolite.

Part 4.—Gold-bearing Alluvium of Chindwin River and Tributaries. Correlation of Siwalik with Mammal Horizons of Europe. Contributions to the Geology of the Province of Yünnan in Western China: III.—Stratigraphy of Ordovician and Silurian Beds of Western Yünnan, with Provisional Palæontological Determinations. Notes on "Camarocrinus Asiaticus" from Burma.

VOL. XLIV, 1914.

Part 1 (out of print).—General Report for 1913. Carbonaceous Aërolite from Rajputana. Nummulites as Zone Fossils, with description of some Burmese species.

Part 2.—Contributions to the Geology of the Province of Yünnan in Western China: IV.—Country around Yünnan Fu. Dyke of white Trap from Pench Valley Coal-field, Chhindwara District, Central Provinces. Mineral concessions during 1913.

Part 3.—Coal-seams near Yaw River, Pakokku District, Upper Burma. The Monazite Sands of Travancore. Lower Cretaceous Fauna from Himalayan Gieumal Sandstone together with description of a few fossils from Chikkim series. Indarctos salmontanus Pilgrim. Future Beheading of Son and Rer Rivers by Hasdo.

Part 4.—Salt Deposits of Cis-Indus Salt Range. Tooth referable to Lower Siwalik Creodont genus 'Dissopsalis' Pilgrim. Glaciers of Dhauli and Lissar Valleys, Kumaon, Himalaya, September 1912. Miscellaneous Notes.

VOL. XLV, 1915.

Part 1.—New Siwalik Primates. Brachiopoda of Namyau Beds of Burma. Miscellaneous Note.

Part 2.—General Report for 1914. Note on Sivælurus and Paramachærodus.

Part 3.—Mineral Production of India during 1914. Three New Indian Meteorites Kuttippuram, Shupiyan and Kamsagar. Dentition of Tragulid Genus (Dorcabune). Hematite Crystals of Corundiform Habit from Kajlidongri, Central India.

Part 4.—Geology of country near Ngahlaingdwin. Geology of Chitral, Gilgit and Pamirs.

VOL. XLVI, 1915.

Quinquennial Review of Mineral Production of India for 1909 to 1913 *(out of print).*

VOL. XLVII, 1916.

Part 1.—General Report for 1915. Eocene Mammals from Burma. Miscellaneous Notes.

Part 2.—The Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Iron Ore Deposits of Twinngé, Northern Shan States.

Part 3.—Obituary: R. C. Burton. The Mineral Production of India during 1915. Flemingostrea, an eastern group of Upper Cretaceous and Eocene Ostreidæ, with descriptions of two new species.

Part 4.—Contributions to the Geology of the Province of Yünnan in Western China: 5.—Geology of parts of the Salween and Mekong Valleys. A fossil wood from Burma. The Visuni and Ekh Khera Aerolites.

Vol. XLVIII, 1917.

Part 1.—General Report for 1916. A revised classification of the Gondwana System.

Part 2.—Mineral Production of India during 1916. Mammal collections from Basal Beds of Siwaliks.

Part 3.—Crystallography and Nomenclature of Hollandite. Geology and Ore Deposits of Bawdwin Mines. Miscellaneous Notes.

Part 4.—Biana-Lalsot Hills in Eastern Rajputana. Origin of the Laterite of Seoni, Central Provinces.

Vol. XLIX, 1918-19.

Part 1.—General Report for 1917. Cassiterite Deposits of Tavoy. Les Echinides des "Bagh Beds."

Part 2.—Mineral Production of India during 1917. Support of Mountains of Central Asia.

Part 3.—Structure and Stratigraphy in North-West Punjab. Aquamarine Mines of Daso, Baltistan. Srimangal Earthquake of July 8th, 1918.

Part 4.—Possible Occurrence of Petroleum in Jammu Province: Preliminary Note on the Nar-Budhan Dome, of Kotli Tehsil in the Punch Valley. Submerged Forests at Bombay. Infra-Trappeans and Silicified Lava from Hyderabad, S. India.

Vol. L, 1919.

Part 1.—General Report for 1918. Potash Salts of Punjab Salt Range and Kohat. Origin and History of Rock salt Deposits of Punjab and Kohat.

Part 2.—Tungsten and Tin in Burma. Inclination of Thrust-plane between Siwalik and Murree zone near Kotli, Jammu. Two New Fossil Localities in Garo Hills. Sanni Sulphur Mine. Miscellaneous Notes.

Part 3 (out of print).—Mineral Production of India during 1918. Gastropoda Fauna of Old Lake-beds in Upper Burma. Galena Deposits of North-Eastern Putao.

Part 4 (out of print)—Pitchblende, Monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. Natural Gas in Bituminous Salt from Kohat. Mineral Resources of Central Provinces. Miscellaneous Notes.

Vol. LI, 1920-21.

Part 1.—General Report for 1919 Pseudo-crystals of Graphite from Travancore. Mineral related to Xenotime from Manbhum District, Bihar and Orissa Province. Coal Seams of Foot-Hills of the Arakan Yoma, between Letpan Yaw in Pakokku and Ngapé in Minbu, Upper Burma. Observations on "Physa Prinsepii," Sowerby and on a Clionid Sponge that burrowed in its shell.

Part 2.—Classification of fossil Cypræidæ. Sulphur near the confluence of the Greater Zab with the Tigris, Mesopotamia. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1919. Results of a Revision of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma. Marine Fossils collected by Mr. Pinfold in the Garo Hills.

Part 4.—Illustrated comparative Diagnoses of Fossil Terebridæ from Burma. Indian Fossil Viviparæ. New fossil Unionid from the Intertrappean beds of Peninsular India. Unionidæ from the Miocene of Burma.

Vol. LII, 1921.

Quinquennial Review of Mineral Production of India for 1914-1918.

Vol. LIII, 1921.

Part 1.—General Report for 1920. Antimony deposit of Thabyu, Amherst district. Antimony deposits of Southern Shan States. Geology and Mineral Resources of Eastern Persia. Miscellaneous Notes.

Part 2.—Comparative Diagnoses of Pleurotomidæ from Tertiary Formation of Burma. Comparative Diagnoses of Conidæ and Cancellariidæ from Tertiary of Burma. Stratigraphy, Fossils and Geological Relationships of Lameta Beds of Jubbulpore. Rocks near Lameta Ghat (Jubbulpore District).

Part 3 (out of print).—Obituary: Frederick Richmond Mallet. Mineral Production of India during 1920. Mineral Resources of Bihar and Orissa.

Part 4.—Stratigraphy of the Singu-Yenangyat Area. Analysis of Singu Fauna. Sulphur Deposits of Southern Persia. A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica.

Vol. LIV, 1922.

Part 1.—General Report for 1921. Contributions to the Geology of the Province of Yünnan in Western China: VI. -Traverses between Tali Fu and Yunnan Fu. Geology of Takki Zam Valley, and Kaniguram-Makin Area, Waziristan. Geology of Thayetmyo and neighbourhood, including Padaukbin. Bitumen in Bombay Island.

Part 2.—Mineral Production of India during 1921. Iron Ores of Singhbhum and Orissa. Geological Results of Mount Everest Reconnaissance Expedition. Northern Extension of Wolfram-bearing Zone in Burma. Miscellaneous Note.

Part 3.—Obituary: Rupert William Palmer. Indian Tertiary Gastropoda. IV.—Olividæ, Harpidæ, Marginellidæ, Volutidæ and Mitridæ, with comparative diagnoses of new species. Structure of Cuticle in Glossopteris angustifolia Brongn. Revision of some Fossil Balanomorph Barnacles from India and the East Indian Archipelago. Contributions to the Geology of the Province of Yünnan in Western China: 7.—Reconnaissance Surveys between Shunning Fu, Chingtung Ting and Tali Fu. 8.—Traverse down Yang-tze chiang Valley from Chin-chaing-kai to Hui-li-Chou. Boulder Beds beneath Utatur State, Trichinopoly District. Miscellaneous Notes.

Part 4.—Geology of Western Jaipur. Geological Traverses from Assam to Myitkyina, through Hukong Valley; Myitkyina to Northern Putao; and Myitkyina to Chinese Frontier. Oligocene Echinoidea collected by Rao Bahadur S. Sethu Rama Rau in Burma. Mineral Resources of Kolhapur State. Kunghka and Manmaklang Iron Ore Deposits, Northern Shan States, Burma.

VOL. LV, 1923-24.

Part 1.—General Report for 1922. Indian Tertiary Gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ, Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species. Geological Interpretation of some Recent Geodetic Investigations (being a second Appendix to the Memoir on the structure of the Himalayas and of the Gangetic Plain as elucidated by Geodetic Observations in India).

Part 2.—Obituary: Ernest (Watson) Vredenburg. Fossil Molluscs from Oil-Measures of Dawna Hills, Tenasserim. Armoured Dinosaur from Lametta Beds of Jubbulpore. Fossil forms of Placuna. Phylogeny of some Turbinellidæ. Recent Falls of Aerolites in India. Geology of part of Khasi and Jaintia Hills, Assam.

Part 3.—Mineral Production of India during 1922. Lignitic Coal-fields in Karewa formation of Kashmir Valley. Basic and Ultra-Basic Members of the Charnockite Series in the Central Provinces. China Clay of Karalgi, Khanapur, Belgaum District.

Part 4.—Obituary: Henry Hubert Hayden. Oil Shales of Eastern Amherst, Burma, with a Sketch of Geology of Neighbourhood. Provisional list of Palæozoic and Mesozoic Fossils collected by Dr Coggin Brown in Yünnan. Fall of three Meteoric Irons in Rajputana on 20th May 1921. Miscellaneous Note.

VOL. LVI, 1924-25.

Part 1.—General Report for 1923. Mineral Deposits of Burma.

Part 2.—Mineral Production of India during 1923. Soda rocks of Rajputana.

Part 3.—Gyrolite and Okenite from Bombay. Freshwater Fish from oil-measures of Dawna Hills. Fossil Ampullariid from Poonch, Kashmir. Calcareous Alga belonging to Triploporelleæ (Dasycladaceæ) from Tertiary of India. Froth Flotation of Indian Coals. Submarine Mud Eruptions off Arakan Coast, Burma. Cretaceous Fossils from Afghanistan and Khorasan.

Part 4.—Morus Meteorite. Stegodon Ganesa in Outer Siwaliks of Jammu. Land and Freshwater Fossil Molluscs from Karewas of Kashmir. Burmese Lignites from Namma, Lashio and Pauk. Maurypur Salt Works.

VOL. LVII, 1925.

Quinquennial Review of Mineral Production of India for 1919-1923. Price 5 Rs. 10 As.

VOL. LVIII, 1925-26.

Part 1.—General Report for 1924. Fossil Tree in Panchet Series of Lower Gondwanas near Asansol, with Palæontological Description.

Part 2.—Obituary: Francis William Walker. Possibilities of finding concealed coal-field at a workable depth in Bombay Presidency. Basaltic Lavas penetrated by deep boring for coal at Bhusawal, Bombay Presidency.

Part 3.—Mineral Production of India during 1924. Enstatite-Augite Series of Pyroxenes. Constitution of the Glauconite and Celadonite. Palagonite-bearing Dolerite from Nagpur.

Part 4.—Fossils Crétacés de l'Afghanistan. Fossiles du Kashmir et des Pamirs. Additions and Corrections to Vredenburg's Classification of the Cypræidæ. Petrology of Rocks from Girnar and Osham Hills, Kathiawar, India.

VOL. LIX, 1926.

Part 1.—General Report for 1925. Foraminifera of parts of Western India.

Part 2.—Sampling Operations in Pench Valley Coal-field. Composition of some Indian Garnets. Geology of Andaman and Nicobar Islands, with special reference to Middle Andaman Island. Occurrence of Cryptohalite. Remarks on Carter's Genus Conulites.

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Part 4.—Low-Phosphorus Coking Coal in Giridih Coal-Field. Distribution of Gault in India. Age of so-called Danian Fauna from Tibet. Bauxite on Korlapat Hill, Kalahandi State, Bihar and Orissa.

VOL. LX, 1927-28.

Part 1.—General Report for 1926. Six Recent Indian Aërolites.

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Part 3.—Mineral Production of India during 1926. Geological Traverse in Yunaslin Valley. Ambala Boring of 1926-27. Indian Unionidæ.

Part 4.—Relationship between Specific Gravity and Ash Contents of Coals of Korea and Bokaro Coals as Colloid Systems. Contact of Basalt with coal-seam in the Isle of Skye, Scotland. Comparison with Indian examples. Batakar-Ironstone Boundary near Begunia, Raniganj Coal-Field. Raniganj-Panchet Boundary near Asansol, Raniganj Coal-Field. Permo-Carboniferous Marine Fauna from Umaria Coal-field. Geology of Umaria Coal-field, Rewah State, Central India. Composition and Nomenclature of Chlorophæite and Palagonite, and on Chlorophæite Series. Miscellaneous Notes.

VOL. LXI, 1928-29.

Part 1.—General Report for 1927. Actionodon risinensis in Lower Gondwanas of Vihi district, Kashmir. Miscellaneous Note: Further Note on Nomenclature of Hollandite.

Part 2.—Contribution to Geology of Punjab Salt Range. Iron Ore Deposits of Northern Shan States. Lower Canine of Indian Species of Conohyus. Miscellaneous Note: Leucopyrite from Kodarma.

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VOL. LXII, 1929-30.

Part 1.—General Report for 1928. Miscellaneous Note: New Chromite Localities.

Part 2.—Obituary: Sivarau Sethu Rama Rau. Specific Gravity and Proximate Composition of Indian Vitrains. New Devonian Fossils from Burma. Rangoon Earthquakes of September and December 1927. Epicentre of North-West Himalayan Earthquake of 1st February 1929. Miscellaneous Notes. Indian Beryl, Atacamite in Bihar and Pyromorphite in Bhagalpur district, Bihar.

Part 3.—Mineral Production of India during 1928. Granophyric Trachite from Salsette Island, Bombay. Coal Resources of Jharia Coalfield. Coal lost by Fires and Collapses in Indian Coal Mines.

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VOL. LXIII, 1930.

Part 1.—General Report for 1929 Upper Triassic Fossils from Burmo-Siamese Frontier.—Thaungyin Trias and Description of Corals. Upper Triassic Fossils from Burmo-Siamese Frontier.—Brachiopoda and Lamellibranchia from Thaungyin River. Upper Triassic Fossils from Burmo-Siamese Frontier.—Fossils from Kamawkala Limestone. Upper Triassic Fossils from Burmo-Siamese Frontier.—New Dasycladacea, *Holosporella siamensis* nov. gen., nov. sp., with Description of Allied Genus *Aciculella* Pia. Cretaceous Cephalopods in 'Red Beds' of Kalaw, Southern Shan States, Burma.

Part 2.—Methods of Analysis of Coal used at Government Test House, Alipore, Calcutta, with an Editorial Introduction. New fossil localities within Panchet series of Raniganj Coal-field. Species of *Cyllene* from Pegu Beds of Burma. Two new species of *Unio*. Glaciers of Karakoram and Neighbourhood. Miscellaneous Note: Dome near Mari in Attock District.

Part 3.—Mineral Production of India during 1929. On the Specific Gravity and Proximate Composition of some Indian Durains.

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VOL. LXIV, 1930.

Quinquennial Review of Mineral Production of India for 1924-1928. Price 9 Rs. 6 As.

VOL. LXV, 1931-32.

Part 1.—General Report for 1930. Additional Note on Samolia Meteorite. Zoning and Difference in Composition of Twinned Plagioclase Felspars in certain rocks from Sirohi State, Rajputana. Albite-Ala B Twinning of Plagioclase Felspars in certain acidic rocks from Sirohi State, Rajputana. Jurassic Fossils from Northern Shan States.

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Part 3.—Mineral Production of India during 1930. Geology and Lead-ore Deposits of Mawson, Federated Shan States. Weathering of Vindhyan Building Stone. *Maclurites* from Ordovician of Burma. Miscellaneous Notes: Supplementary note on "Revisions of Indian Fossil Plants, Part II Coniferales (*b.* Petrifactions), 1931" and Eruption of Mud Volcano off Arakan Coast.

Part 4.—Reaction Minerals in Garnet-Cordierite-Gneiss from Mogok. Vindhyans of western Rajputana. Granitic Intrusions in Ranchi and Singhbhum Districts. Miscellaneous Notes: *Chonetes* in Krol Limestone; Green Mica from Bhandara District; and Olivine-Basalt and Tuffs in Malani Series at Jodhpur.

VOL. LXVI, 1932-33.

Part 1.—General Report for 1931. Rudistæ from Eastern Persia.

Part 2.—Lower Palæozoic Fossils from the Southern Shan States. Geology of Nanga Parbat (Mt. Diamir) and adjoining portions of Chilas, Gilgit District, Kashmir. Fossil Plants from Parsora Stage, Rewa. Swa Earthquake of August 8th, 1929. Overlap in the Ngape Area, Minbu District. Miscellaneous Note: Ammonite from Ramri Island.

Part 3.—Mineral Production of India during 1931. Microscopic Study of some Indian Coals. Specific Gravity and Porosity of Indian Building Stones. Indian Seismological Records of Chief Shocks in N. E. Frontier Region of Burma during 1929 and 1930. Glacier in Arwa Valley, Garhwal.

Part 4.—Stratigraphic significance of Fusulinids of Lower Productus Limestone of Salt Range. *Dadoxylon Zalesskyi*, a new Species of Cordaitean trees from Lower Gondwanas of India. Fossil Pentalocular Fruit from Pondicherry. Kalava (Calwa) 'Wall' in Kurnool District. Talc-Serpentine Chlorite Rocks of Southern Mewar and Dungarpur. Age of certain Himalayan Granites. Tables of Production, Imports, Exports and Consumption of Minerals and Metals in India.

VOL. LXVII, 1933-34.

Part 1.—General Report for 1932. Anthracolithic Faunas of Southern Shan States.

Part 2.—Geological Reconnaissance in Southern Shan States. Geology of the country between Kalaw and Taunggyi, Southern Shan States.

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Part 4.—Geology of the Krol Belt. Crush Conglomerates of Dharwar Age from Chota Nagpur and Jubbulpore.

VOL. LXVIII, 1934-35.

Part 1.—General Report for 1933. Obituary: Malhari Vinayak Rao. Khanpur Meteoric Shower. Cambrian Sequence of Punjab Salt Range.

Part 2.—Cambrian Trias Sequence of North Western Kashmir (Parts of Muzaffarabad and Baramula Districts). Preliminary account of Earthquake of 15th January, 1934, in Bihar and Nepal. Obituary: Pramatha Nath Bose. Miscellaneous Notes: Barytes in Manbhum District, Bihar; Soda Deposit and Manufacture of Caustic Soda and Crude Soap at Paran-tij, Ahmedabad District; Potash content of *Reshta*, Sambhar Salt Lake, Rajputana; Alunogen from Cuddapah District; and Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1934.

Part 3.—Mineral Production of India during 1933. Manganese Lime Series of Garnets. Chemical Composition of Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1934.

Part 4.—Soils of India. Lateritisation of Khondalite. Snout of Biafo Glacier in Baltistan. Turonian Ammonite (*Mammites Daviesi*) from Ramri Island, Burma. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1934; Tertiary Rocks near Puri; and Cretaceous and Eocene Volcanic Rocks of the Great Himalaya Range in North Kashmir.

VOL. LXIX, 1935-36.

Part 1.—General Report for 1934. Primitive Fossils, possibly Atrematous and Neotrematous Brachiopoda, from the Vindhyans of India. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December 1934, and Additional Note on Nomenclature of Hollandite.

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Part 4.—Buchanan's Laterite of Malabar and Kanara. Solubility of Quartz. Natural Gas at Gogha, Kathiawar. Patwar Meteoric Shower of the 29th July, 1935. *Fermoria minima*: A Revised Classification of Organic Remains from Vindhyans of India. Ore minerals from Bawdwin, Shan States. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1935.

VOL. LXX, 1936.

Quinquennial Review of Mineral Production of India for 1929-1933. Price 6 Rs. 4 As.

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Part 1.—General Report for 1935. Dyke Rocks of Keonjhar State, Bihar and Orissa. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1935.

Part 2.—Perpeti Meteoric Shower of 14th May, 1935. Tirupati and Bahjoi Meteorites. *Ostrea* (*Crassostrea*) *gajensis* from near Baripada, Mayurbhanj State. *Matonidium* and *Weichselia* in India. Cretaceous Cephalopods from Red Beds of Kalaw and Age of Red Beds. Contributions to the Geology of the Province of Yünnan in Western China: 9.—Brachiopod Beds of Liu-wun and related formations in Shan States and Indo-China. Geological Age of Namyau, Liu-wun and Napeng Beds and of certain other formations in Indo-China. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1936.

Part 3.—Mineral Production of India during 1935. Marble of the North-West Frontier Province. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1936.

Part 4.—Obituary: Richard Dixon Oldham. Geology of Second Defile of Irrawaddy River. *Orbitolina*-bearing rocks in Burma: with description of *Orbitolina birmanica*, sp. nov. Rocks in vicinity of Kyaukse, Burma. Mesozoic coniferous wood (*Mesembrioxylon shanense*, sp. nov.) from Southern Shan States of Burma. Foraminifera from Intertrappean Beds near Rajahmundry. *Holosporella* cf. *H. Siamensis Pia*, from Rajahmundry Limestones. Maleri beds of Hyderabad State (Deccan) and Tiki Beds of South Rewa. Structure of Himalaya in Garhwal. Miscellaneous Notes: Coaly Shale in Deccan Trap in Indore, Central India. Octahedral Pyrite Crystals from Kohat District, North-West Frontier Province. Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1936.

VOL. 72, 1937.

Part 1.—General Report for 1936. Note on 'coalite'. Freshwater and Land Fossil Molluscs from near Ghorband, Afghanistan. Provisional statistics of some of the more important Indian Minerals for 1936. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1936.

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VOL. 73, 1938.

Part 1.—General Report for 1937. Hindu Kush Earthquake of 14th November, 1937. Khoharite, a New Garnet and on the Nomenclature of Garnets. Provisional Statistics of some of the more important Indian minerals for 1937. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma: October to December, 1937.

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NOTICE.

Records, Vol. 73, Part 2 is in the press and will be issued later.

““# RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1938. [October.

THE MINERAL PRODUCTION OF INDIA AND BURMA DURING 1937. BY A. M. HERON, D.Sc., F.G.S., F.R.G.S., F.R.S.E., F.R.A.S.B., F.N.I., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII, 1905), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. As the methods of collecting the returns become more precise, and the machinery employed for the purpose more efficient, the number of minerals included in Class I—for which approximately trustworthy annual returns are available—increases, and it is hoped that the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will in time be reduced to a very small number. In the case of minerals still exploited chiefly by primitive Indian methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible; the total error from year to year, however, is characterised by some degree of constancy, and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that the error from this source may be regarded as negligible.

Since the figures of mineral production published in these Reviews are in many cases greater than those published in the Annual Returns of the Chief Inspector of Mines, it is desirable to explain that the figures published by the Chief Inspector of Mines are confined to mines and workings that come under the Mines Act, which relates only to British India; whereas the figures published in these Reviews include the production of both Act and non-Act

workings in British India, and also the production of the Indian States. For the provision of the data we are indebted to the Chief Inspector of Mines and the Local Governments in respect of British India, to the Indian Durbars and Political Agents in the case of Indian States, and to the Managements of the mining companies. On the 1st April, 1937, the separation of Burma from India took place, and Tables 1 and 2 show the values of minerals produced in the two countries separately, instead of in one combined table, as in former years.

The average value of the Indian rupee during the year 1937 was 1*s.* $6\frac{3}{32}$*d.*; the highest value reached was 1*s.* $6\frac{1}{8}$*d.* and the lowest 1*s.* $6\frac{3}{32}$*d.* The values for 1936 shown in the tables are given on the basis of 1*s.* $6\frac{3}{32}$*d.* to the rupee; for ease of calculation, £1 has been taken to be equivalent to Rs. 13·3 instead of Rs. 13·27.

Tables 1 and 2 show the total value of minerals for which returns of production are available for the years 1936 and 1937. The average figure for the quinquennium, 1919-1923, was £25,194,123· In the following year, 1924, there was an apparent increase of over £3,500,000; this was, in part, however, due to the higher average value of the rupee during that year. Since 1924, there was a steady decline down to the year 1928, for which the value was £21,888,528. There was an arrest in this decline in 1929, which showed an increase in total value to £22,328,686, or about 2 per cent. over that of 1928. In 1930, however, the decline was resumed and the total value of the production fell annually to £15,612,235 in 1932. In 1933, the tide turned again and the total value of the output increased by nearly £1,000,000 to £16,599,837. This rise continued in 1934 when the total value increased by £1,068,550 to £17,668,387 and in 1935, by £1,678,493 to £19,346,880 (revised figure). In 1936 there was a smaller increase of £76,431 to £19,274,341, and in 1937 a great increase of £5,944,236 to £25,218,577, for India and Burma combined,

The aggregate increase in the value of the production of all minerals in India was £4,104,802 or 34·7 per cent. and in Burma was £1,839,434 or 24·9 per cent.

Coal and petroleum remain at the head of the list, with production figures of over five and a half millions sterling, and manganese-ore has displaced gold in the third place, with three millions four hundred thousand sterling.

Of the minerals with a value of over £100,000 annually, percentage increases, to the extent given, are shown by coal in India of 25·0, petroleum in Burma of 19·7 and in India of 12·6, manganese-ore in India of 187·2, mica in India of 56·5, lead in Burma of 41·9, building-materials in India of 10·6 and in Burma of 22·9, tin concentrates in Burma of 5·5, salt in India of 10·5 and in Burma of 66·5, tungsten concentrates in Burma of 96·1 with a revival of a long-suspended small production in India, copper-ore in India of 21·7 and copper-matte in Burma of 20·3, iron-ore in India of 17·3, silver in Burma of 7·1, and zinc concentrates in Burma of 34·8.

Of these more important minerals, gold shows a trifling fall in value of 0·3 per cent. from India and 19·0 per cent. on Burma's small production, and nickel-speiss from Burma of 6·2 per cent.

Of the less important minerals, spectacular increases have taken place in the production values of what may be termed the industrial minerals, given in percentages, *e.g.*, ilmenite 35·7, chromite 38·2, refractories 87·8, magnesite 60·4, barytes 830·6, monazite 30·0, gypsum 20·5, fuller's earth 4·7, bauxite 748·6, graphite 270·4, asbestos 93·6, and apatite 26·3.

Apart from gold and nickel-speiss, decreases in value took place only in the case of minerals with small and erratic outputs, such as steatite, diamonds, zircon, ochres, felspar, beryl, garnet, ruby and sapphire, and jadeite.

TABLE 1.—*Total value of Minerals for which returns of production in India are available for the years 1936 and 1937.*

——	1936.	1937.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	4,699,128	5,872,364	1,173,236	..	+25·0
Manganese-ore (*a*)	1,124,422	3,229,554	2,105,132	..	+187·2
Gold	2,293,113	2,285,404	..	7,709	—0·3
Mica (*b*)	689,963	1,079,702	389,739	..	+56·5
Petroleum	915,188	1,030,591	115,403	..	+12·6
Building materials	658,501	728,562	70,061	..	+10·6
Salt	554,099	612,584	58,485	..	+10·5
Copper-ore	300,993	366,280	65,287	..	+21·7
Iron-ore	294,125	344,840	50,715	..	+17·3
Ilmenite	62,423	84,686	22,263	..	+35·7
Saltpetre (*b*)	86,273	84,048	..	2,225	—2·5
Chromite	45,450	62,826	17,376	..	+38·2
Refractory materials	29,798	55,970	26,172	..	+87·8
Clays	(c)22,057	24,229	2,172	..	+9·4
Magnesite	7,684	12,326	4,642	..	+60·4
Steatite	11,803	11,671	..	132	—1·1
Barytes	1,206	11,223	10,017	..	+830·6
Monazite	8,116	10,554	2,438	..	+30·0
Gypsum	7,396	8,913	1,517	..	+20·5
Fuller's earth	5,389	5,640	251	..	+4·7
Bauxite	548	4,650	4,102	..	+748·6
Diamonds	4,675	4,134	..	541	—11·6
Zircon	6,335	2,935	..	3,400	—53·7
Silver	2,528	2,432	..	96	—3·8
Tungsten-ore	..	1,842	1,842	..	..
Ochres	(c)2,749	1,788	..	961	—34·9
Graphite	331	1,226	895	..	+270·4
Asbestos	234	453	219	..	+93·6
Felspar	454	255	..	199	—43·8
Beryl	466	148	..	318	—68·2
Apatite	99	125	26	..	+26·3
Garnet	5	124	119	..	..
Bentonite	102	68	..	34	—33·3
Sapphire	1,682	41	..	1,641	—97·6
Tantalite	76	23	..	53	—69·7
Soda	..	2	2	..	..
TOTAL	11,837,411	15,942,213	4,122,111	17,309	+34·7
			+4,104,802		

(*a*) Exports f.o.b. values. (*b*) Export values. (*c*) Revised.

TABLE 2.—*Total value of Minerals produced in Burma, for which figures of production are available for the years 1936 and 1937.*

—	1936.	1937.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Petroleum (*a*) . . .	3,736,805	4,474,147	737,342	..	+19·7
Lead	1,269,262	1,801,719	532,457	..	+41·9
Tin concentrates . .	780,689	824,001	43,312	..	+5·5
Tungsten concentrates .	307,624	603,214	295,590	..	+96·1
Silver	516,660	553,458	36,798	..	+7·1
Zinc concentrates . .	303,356	409,054	105,698	..	+34·8
Building materials . .	158,211	194,550	36,339	..	+22·9
Copper-matte . . .	151,126	181,839	30,713	..	+20·3
Nickel-speiss . . .	111,489	104,590	..	6,899	—6·2
Salt	37,257	(*a*)62,026	24,769	..	+66·5
Antimonial lead. . .	26,036	31,652	5,616	..	+21·5
Jadeite	13,412	13,030	..	382	—2·8
Iron-ore (*a*) . . .	7,915	7,647	..	268	—3·4
Ruby and sapphire . .	7,319	7,069	..	250	—3·4
Gold	7,820	6,333	..	1,487	—19·0
Clays . . .	1,540	1,367	..	173	—11·2
Amber	409	668	259	..	+63·3
TOTAL .	7,436,930	9,276,364	1,848,893	9,459	+24·9
			+1,839,434		

(*a*) Estimated.

It is interesting to compare the changes in the figures of total value recorded in Tables 1 and 2 with the variations in the average

annual value of the leading metals and ores as summarised in Table 3. In 1931 all the metals and ores given in this table showed a fall in price except gold, in the price of which there was a substantial rise. In 1932 there was a very large rise in the price of gold, and in addition a partial recovery in the price of spelter, tin and silver. In 1933 there were small falls in the price of lead and chromite; the prices of steel rails, ferro-manganese and manganese-ore were stationary; whilst the prices of other metals and ores rose, the largest rise being that of tin. In 1934 there was a spectacular rise in the price of wolfram, and further substantial rises in the prices of tin, gold and silver, with a small rise in the prices of manganese-ore and pig-iron; on the other hand there were falls in the prices of copper, lead, spelter, petrol and kerosene, whilst the prices of steel rails, ferro-manganese, and chromite were stationary. In 1935 prices were much steadier, with a general upward tendency, except in the cases of tin, chromite and wolfram, which declined slightly, steel rails and ferro-manganese being stationary. In 1936, the general upward tendency continued except in the cases of tin, wolfram, gold and silver, which declined, rails again being stationary. In 1937, there was a marked rise in all prices except in the cases of gold and silver, in which the rise was very slight, and chromite, which declined slightly.

The number of mineral concessions granted in 1937 was 291 prospecting licenses, 57 mining leases, and 25 quarry leases in India and 271 prospecting licenses and 46 mining leases in Burma. The total, 690, when compared with the figures for 1932 (327), 1933 (406), 1934 (482), 1935 (567) and 1936 (531), shows how interest in mining enterprise is reviving after the period of depression. The highest number granted in one year was 859 in 1925.

The average number of persons employed daily during 1937 in India was 373,129 against 342,766 in the previous year, as recorded in Table 4. The figures for Burma for 1937 are not available. It will be seen that the most important mineral industries in providing employment are, in order, coal, salt, manganese-ore, mica, gold, and iron-ore. In addition much additional employment is, of course, provided in the transport, smelting and refining industries.

In Part 4 of Volume LXVI of these *Records* is a paper giving tables of production, imports, exports, and of consumption of minerals and metals in India for 1913, 1917, 1920, and 1926 to 1931.

These data are given in considerable detail and similar data could not easily be obtained in full in time for incorporation in

TABLE 3.—*Average Prices in the United Kingdom of Principal Metals, Ores and Oils during the years 1936 and 1937.*

—		1936.	1937.
Metals—			
Copper, standard, per ton	£	38·47	54·50
Lead, pig, soft, foreign, per ton	£	17·58	23·30
Spelter, ordinary, per ton	£	15·03	22·34
Tin, standard, per ton	£	204·63	242·33
Pig iron, Cleveland No. 3, per ton	£	3·65	4·60
Steel rails, per ton	£	8·37	9·55
Ferro-manganese, per ton	£	11·808	16·60
Gold, fine, per ounce	sh.	140·291	140·666
Silver, standard, per ounce	d.	20·059	20·071
Ores—			
Chromite, 48-57 per cent., per ton	£	4·596	4·425
Manganese-ore, first grade, per unit	d.	12·26	22·50
Wolfram, per unit	sh.	31·646	69·833
Oils—			
Petrol, per gallon	d.	9·0	10·0
Kerosene, per gallon	d.	7·25	8·50

successive annual reviews of mineral production without causing undue delay. It is possible, however, to bring up to date Table V of that review showing the quantities of ores, metals and other mineral products available for consumption in India. These data for 1937 are summarised in Table 5 of this present review.

TABLE 4.—*Average number of persons employed daily in 1936 and 1937 in the production of minerals from mines in India for which reliable returns of labour statistics are available. (Figures for Burma not included.)*

——	1936.	1937.
Chromite	2,207	2,689
Coal	181,687	194,705
Copper-ore	2,878	3,216
Diamonds	1,246	983
Gold	23,103	24,119
Iron-ore	21,118	20,043
Magnesite	1,163	1,674
Manganese-ore	20,796	30,208
Mica	25,151	29,421
Monazite, ilmenite, zircon	3,513	3,430
Petroleum	4,343	6,866
Salt	55,561	55,625
Tungsten concentrates	.	150
TOTAL	342,766	373,129

TABLE 5.—*Consumption in India during the year 1937.*

Ores, minerals and metals. 1	Kinds and grades. 2	Unit. 3	Production. 4	Retained imports into India (a). 5	Exports of domestic production. (a) 6	Ores, minerals and metals available for consumption columns 4 + 5 — 6. 7
Aluminium	**Aluminium unwrought (ingots, blocks, etc.)**	Cwts.	..	80	..	80
	Bauxite	Tons	15,150	..	(b)	..
Arsenic	**Arsenic and its oxides**	Cwts.	(c)	5,791	..	5,791
Asbestos	....	Tons	100	(d)	..	..
Barytes	....	Tons	15,689	439	..	16,128
Bentonite	....	Tons	90	..	..	90
Beryl	....	Tons	27	..	(b)	..
Borates	**Borax**	Cwts.	(c)	34,593	..	34,593
Brass	....	Tons	10,019	10,167	1,089	19,097
Clays	**Clays other than China clay.**	Tons	311,816	..	..	311,816
	China clay	Tons	17,081	31,794	..	48,875
Chrome-ore	**Chromite**	Tons	62,307	..	(e)50,367	11,940
Coal, Coke and bye-products.	**Bituminous non-coking coal, bituminous coking coal, anthracite.**	Tons	25,036,386	64,850	873,310	24,227,926
	Coal tar and pitch	Tons	69,705	2,852	..	72,557
	Sulphate of ammonia	Tons	18,150	48,136	1,919	64,367
Copper	**Metal unwrought**	Tons	6,830	2,345	..	9,175
Diamonds	....	Carats.	1,178	(f)	..	1,178
Ferro-manganese	....	Tons	8,041	..	..	8,041
Ferro alloys	....	Tons	..	2,437	..	2,437
Felspar	....	Tons	487	..	..	487
Fuller's earth	....	Tons	7,416	..	..	7,416

(a) Including Burma up to 31st March, 1937.
(b) Known to be exported but export figures are not available.
(c) Known to be produced, but production figures are not available.
(d) Complete figures for quantity are not available; value Rs. 17,56,920.
(e) Includes 13,282 tons produced in India but exported from Mormugao in Portuguese India.
(f) Quantity unknown. Value of diamonds imported in 1937 amounted to Rs. 97,69,C06.

TABLE 5.—*Consumption in India during the year 1937*—contd.

Ores, minerals and metals.	Kinds and grades.	Unit.	Production.	Retained imports into India (*a*).	Exports of domestic production. (*a*)	Ores, minerals and metals available for consumption columns 4+5—6.
1	2	3	4	5	6	7
Garnet sand .	....	Tons	330	..	(*b*)	..
Gold . . .	....	Fine ounces.	330,744	208,556	(*c*)1,971,126	..
Graphite . .	....	Tons	558	582	..	1,148
Gypsum . .	....	Tons	46,090	..	..	46,090
Ilmenite . .	....	Tons	181,047	..	204,653	..
Iron . . .	Ore	Tons	2,870,832	..	..	..
	Pig	Tons	1,621,260	1,566	597,331	1,025,495
	Steel . . .	Tons	665,309	93,669	6,803	752,175
	Manufactures of iron or steel other than those included under steel.	Tons	(*d*)	227,409	91,654	135,755
Magnesite . .	....	Tons	26,166	..	8,014	18,152
Manganese-ore .	....	Tons	1,051,594	..	(*e*)1,151,834	..
Mica . . .	....	Cwts,	104,478	..	297,343	..
Monazite .	....	Tons	3,081	..	3,757	..
Ochre .	....	Tons	4,057	..	..	4,057
Petroleum . .	Crude . . .	Gallons	75,657,857	..	..	..
	Natural gas gasolene .	Gallons	456,780	..	..	..
	Petrol including benzene and dangerous spirit.	Gallons	14,957,699	87,784,464	26	102,742,137
	Kerosene . . .	Gallons	36,233,370	162,850,131	352	199,082,872
	Fuel oil . . .	Gallons	1,796,571	127,809,056	..	129,605,627
	Batching and lubricating oils.	Gallons	2,064,322	33,621,352	..	35,685,674
	Paraffin wax . .	Tons	10,626	1,377	25,447	..

(*a*) Including Burma up to 31st March, 1937.
(*b*) Known to be exported but export figures are not available.
(*c*) Total exports, largely imported in previous years.
(*d*) Not available.
(*e*) Includes 170,645 tons produced in British India but exported from Mormugao in Portuguese India.

TABLE 5.—*Consumption in India during the year 1937*—concld.

Ores, minerals and metals.	Kinds and grades.	Unit.	Production.	Retained imports into India (a).	Exports of domestic production. (a)	Ores, minerals and metals available for consumption. columns 4+5—6.
1	2	3	4	5	6	7
Phosphates .	....	Tons	166	10,951	..	11,117
Potash minerals and chemicals including saltpetre.	Saltpetre . . .	Cwts.	(b)177,147	167,147	..	10,000
	Potash chemicals and manures.	Cwts.	..	130,130	..	130,130
Quicksilver .	....	Lbs.	..	235,706	..	235,706
Refractory materials.	....	Tons	(c)47,543	(d)	..	..
Salt . . .	....	Tons	1,493,021	338,986	..	1,832,007
Silver. . .	....	Ounces	24,642	54,510,495	5,311,827	49,223,310
Steatite . .	....	Tons	13,040	..	..	13,040
Sulphur . .	....	Cwts.	..	619,738	..	619,738
Tungsten . .	Ore	Tons	(d)13	..	..	..
Zircon . .	....	Tons	1,329	..	1,037	292

(a) Including Burma up to 31st March, 1937.
(b) 167,647 cwts. exported and 10,000 cwts. consumed in the tea gardens in India.
(c) Includes 29,321 tons of kyanite.
(d) Known to be exported, but export figures are not available.

TABLE 6.—*Quantity and Value of all Minerals and Mineral Oils exported from Burma during the year ended the 31st December 1937.*

Articles. (1)	Unit. (2)	To Foreign Countries. Quantity. (3)	Value. (4)	To India. Quantity. (5)	Value. (6)	Total. Quantity. (7)	Value. (8)
			Rs.		Rs.		Rs.
Precious Minerals—							
Jadestone . .	Cwt.	2,410	1,28,912	..	..	2,410	1,28,912
Rubies . . .	Value	..	5	..	..	..	5
Gold bullion . .	F. oz.	500	46,749	..	..	500	46,749
Silver-bar .	Std. oz.	1,774,209	21,43,569	4,766,167	54.22,111	6,540,376	75,65,680
Other precious stones	Value	..	7,682	..	..	..	7,682
Other minerals —							
Copper ingots . .	Cwt.	..	..	7	605	7	605
Copper matte . .	,,	154,717	24,58,790	..	..	154,717	24,58,790
Pig-lead . . .	,,	1,427,504	2,80,64,789	145,604	28,48,761	1,573,108	3,09,13,550
Lead, other sorts .	,,	180,811	4,82,831	3,283	44,072	184,094	5,26,903
Tin-ore . . .	Ton	2,806	56,68,040	..	..	2,806	56,68,040
Tin-blocks . .	Cwt.	70	9,011	4,914	7,98,664	4,984	8,07,675
Wolfram-ore . .	Ton	10,110	1,75,71,490	..	..	10,110	1,75,61,490
Zinc concentrates .	Cwt.	1,653,513	54,92,346	216	3,020	1,653,729	54,95,366
Chalk and lime . .	,,	..	..	324	1,693	324	1.693
Mineral oil of all kinds	Gal.	53,233	54,508	203,664,815	12,51,53,719	203,718,048	12,52,08,227
Stone and marble .	Ton	(10 cwt.)	314	(*a*)	185	..	499
TOTAL .	..	..	6,21,29,036	..	13,42,72,830	..	19,64,01,866

(*a*) Weight not recorded.

There were 5,175·68 tons of mixed tin and wolfram concentrates valued at Rs. 10,749,855 exported from the Mawchi Mines Ltd.

TABLE 7.—*Quantity and Value of all Minerals and Mineral Oils imported into Burma during the year ended the 31st December 1937.*

Articles.	Unit.	From Foreign Countries		From India.						Grand Total.	
				Indian Merchandise		Foreign Merchandise.		Total.			
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			Rs.		Rs.		Rs.		Rs.		Rs.
Precious minerals—											
Diamonds	Value	..	10,29,852	..	..	..	..	..	..	..	10,29,852
Pearls	,,	..	2,697	..	..	..	..	..	..	..	2,697
Other precious stones	,,	..	2,68,939	..	..	..	..	..	..	..	2,68,939
Gold (uncoined)	F. oz.	20	1,205	..	..	..	..	..	..	20	1,205
Silver	Std. oz.	86,656	104,607	1,424	3,798	..	..	1,424	3,798	88,080	1,08,405
Other minerals—											
Chalk and lime (including French chalk).	Cwt.	6,599	18,530	499	2,864	21	94	520	2,958	7,119	21,438
China clay	,,	211	1,306	21	82	..	..	21	•82	232	1,388
Clay	,,	9,533	31,171	6,183	12,593	..	..	6,183	12,593	15,716	43,764
Coal	Ton	29,262	5,58,044	283,735	42,15,889	..	..	283,735	42,15,889	312,997	47,73,933
Copper ingots	Cwt.	13	624	320	12,840	40	2,223	360	15,063	373	15,687
Iron ore	Ton	(a)	9	200	9,223	..	..	200	9,223	..	9,232
Iron, pig	,,	392	37,803	655	27,158	..	..	655	21,158	1,047	64,961
Tin blocks	Cwt.	850	1,59,184	..	..	29	5,470	29	5,470	879	1,64,654
Lead (unwrought). ingot.	,,	..	..	50	1,630	..	..	50	1,630	50	1,630
Zinc blocks	,,	..	..	(a)	7	..	..	..	7	..	7
(b) Antimony ore	,,	..	..	..	..	..	..	..	..	..	..
Ores (unenumerated)	Ton	38	3,511	1,119	40.982	..	..	1,119	40,982	1,157	44,493
Mica blocks	Cwt.	(a)	434	..	..	..	..	..	..	..	434
(b) Red ochre	,,	..	..	..	..	..	..	..	..	..	..
Fuel oil	Gal.	25,699,897	48,06,618	2,084	956	642	322	2,726	1,278	25,702,623	48,07,896
Kerosene oil in tins	,,	880,000	4,53,750	327,301	2,38,394	8,204	8,253	335,505	2,46,647	1,215,505	7,00,397
Lubricating oil	,,	881,827	13,24,419	13,371	16,981	37,997	90,026	51,368	1,07,007	933,195	14,31,426
Petroleum, dangerous	,,	16,276	32,598	257	378	8	8	265	386	16,541	32,984
Paint solution, dangerous.	,,	21,161	4,486	..	..	..	..	..	..	21,161	4,486
White oil	,,	184,232	1,69,383	1,280	2,420	40	40	1,320	2,280	185,552	1,71,663
Oil—other kinds	,,	109,786	94,503	49.598	28,257	20,021	22,487	69,619	50,744	179,405	1,45,247
Stone and marble	Ton	96	5,470	54	7,340	(a)	70	..	7,410	..	12,880
TOTAL	..	..	91,09,143	..	46,21,612	..	1,28,993	..	47,50,605	..	1,38,59,748

(a) Weight not recorded.
(b) Figures not ascertainable.

H. MINERALS OF GROUP I.

Antimony.

The production of antimonial lead obtained as a bye-product in the lead refinery at the Namtu smelter of the Burma Corporation Limited, decreased from 1,240 tons valued at Rs. 3,46,277 (£26,036) in 1936, to 1,150 tons, valued at Rs. 4,20,976 (£31,652) in 1937. This product contains 81·66 per cent. of lead, 17·69 per cent. of antimony, 0·21 per cent. of copper and 3·44 ozs. of silver to the ton, and is exported for further treatment.

An output of 183 tons of antimony-ore, valued at Rs. 18,240 (£1,371) was reported from the Amherst district, and 16 tons, valued at Rs. 1,056 (£79) from the Thaton district, Burma, in 1936. The output was 67·3 tons in 1937, but the value and district of origin have not been reported by the Burma Government.

Chromite.

There was an increase of 26 per cent. in the production of chromite in India, from 49,486 tons in 1936 to 62,307 tons in 1937. The total exports from India during the year were nearly 12,000 tons more than those of the previous year, and were about 12,000 tons less than the production, amounting to 50,367 tons, made up of 37,085 tons from British India and 13,282 tons from Mormugao in Portuguese India, as compared with 24,988 tons and 13,890 tons respectively in the previous year. The value per ton was Rs. 13·4, as against Rs. 12·2 for 1936.

TABLE 8.—*Quantity and value of Chromite produced in India during the years 1936 and 1937.*

	1936			1937.		
	Quantity	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Baluchistan—						
Quetta-Pishin				45	675	51
Zhob . .	21,089	3,07,505	23,121	27,164	4,04,540	30,417
Bihar						
Singhbhum .	7,053	83,899	6,308	7,678	1,07,258	8,064
Bombay—						
Ratnagiri .		.		500	(*a*)5,000	376
Eastern States Agency—						
Seraikela .	..		.	520	5,200	391
Mysore State—						
Hassan .	12,828	96,562	7,260	16,148	1,35,572	10,193
Mysore .	8,516	1,16,526	8,761	10,252	1,77,344	13,334
TOTAL .	49,486	*6,04,492*	*45,450*	62,307	*8,35,589*	*62,826*

(*a*) Estimated

Coal.

In 1931, 1932 and 1933 there was a continuous decrease in production of coal from the peak figure of 23,803,048 tons in 1930. In 1934 the direction of change was reversed and production increased by 2,268,284 tons (or 11·4 per cent.) from 19,789,163 tons in 1933 to 22,057,447 tons in 1934. In 1935 the increase continued but at a less rate, by 959,248 tons (or 4·3 per cent.), to 23,016,695 tons. In 1936 there was again a decrease by 405,874 tons (1·8 per cent.) to 22,610,821 tons, followed, however, in 1937 by an increase of 2,425,565 tons (10·7 per cent.) to 25,036,386, the highest output

yet recorded. This increase was shared by all provinces except Bengal and the Central Provinces, which showed slight decreases. All fields showed increased production, except Raniganj, Pench Valley and Giridih, and the unimportant fields of Rajmahal Hills, Raigarh State, Khasi and Jaintia Hills and Shahpur (Punjab).

As usual the output of the Tertiary fields was but a trival proportion of the whole, the proportions being 98·13 per cent. from the Gondwana coalfields and 1·87 per cent. from the Tertiary coalfields.

The variations in the statistical position of the coal industry since 1927 can be gauged to some extent by examining the stock position at the end of each year. Stocks increased continuously from 1929 to 1932. In the 1933 review it was recorded that during 1933 the position showed no substantial change, but that the slight reduction of stocks might be symptomatic of a tendency towards a better adjustment of production to demand. This surmise has proved to be partially correct, for during 1934 stocks were reduced by nearly 700,000 tons, increasing by 165,529 tons in 1935 and decreasing by 207,524 tons in 1936 and by 83,609 tons in 1937. The data are given in the following table :—

Year.	Opening Stock.	Closing Stock.	Reduction during year.
	Tons.	Tons.	Tons.
1927	2,161,806	1,721,288	440,518
1928	1,721,288	1,625,717	95,571
1929	1,625,717	844,240	781,477
1930	844,240	986,006	(*a*) 141,766
1931	986,006	1,414,340	(*a*) 428,334
1932	1,414,340	1,664,969	(*a*) 250,629
1933	1,664,969	1,646,248	18,721
1934	1,646,248	949,625	696,623
1935	949,625	1,115,154	(*a*) 165,529
1936	1,115,154	907,630	207,524
1937	907,630	824,021	83,609

(*a*) Increase of stocks.

The increased output of 10·7 per cent. in 1937 was accompanied by an increase of 25·0 per cent. in the total value of the coal produced in India from Rs. 6,24,98,404 (£4,699,128) in 1936, to Rs. 7,81,02,439 (£5,872,364) in 1937.

There was an increase of 5 annas 8 pies in the pit's mouth value per ton of coal for India as a whole, namely from Rs 2-12-3 to Rs. 3-1-11. Increase in value was recorded from all provinces with the exception of Assam, the Central Provinces, Eastern States Agency, Hyderabad and Rajputana (Table 10).

TABLE 9.—*Provincial production of Coal during the years 1936 and 1937.*

——	1936.	1937.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	203,239	248,563	45,324	..
Baluchistan	8,099	17,479	9,380	..
Bengal	6,667,841	6,527,820	..	140,021
Bihar	12,016,914	13,836,717	1,819,803	..
Central India	329,488	334,291	4,803	..
Central Provinces	1,507,982	1,504,159	..	3,823
Eastern States Agency	806,432	1,244,988	438,556	..
Hyderabad	852,739	1,076,241	223,502	..
Orissa	31,061	47,127	16,066	..
Punjab	156,849	166,632	9,783	..
Rajputana	30,177	32,369	2,192	..
TOTAL	22,610,821	25,036,386	2,569,409	143,844

TABLE 10.—*Value of Coal produced in India during the years 1936 and 1937.*

—	1936			1937.		
	Value (£1 = Rs. 13·3).		Value per ton.	Value (£1 = Rs. 13·3).		Value per ton.
	Rs.	£	Rs. A. P.	Rs.	£	Rs. A. P.
Assam	17,02,950	128,041	8 6 1	19,25,409	144,768	7 11 11
Baluchistan . . .	45,571	3,426	5 10 0	1,09,713	8,249	6 4 5
Bengal	1,70,40,371	1,281,231	2 8 11	2,10,13,790	1,579,984	3 3 6
Bihar	3,15,13,969	2,369,472	2 0 11	4,09,23,918	3,076,986	2 15 4
Central India . . .	11,36,189	85,428	3 7 2	11,77,547	88,537	3 8 4
Central Provinces . .	50,23,918	377,738	3 5 0	49,80,150	374,447	3 4 11
Eastern States Agency .	24,86,987	186,992	3 1 4	36,20,601	272,226	2 15 10
Hyderabad . . .	27,16,474	204,246	3 3 0	32,17,860	241,944	2 15 11
Orissa	90,006	6,767	2 14 4	1,50,528	11,318	3 2 4
Punjab	6,03,504	45,376	3 13 7	8,36,790	62,917	5 0 4
Rajputana . . .	1,38,465	10,411	4 9 5	1,46,133	10,988	4 8 3
TOTAL	**6,24,98,404**	**4,699,128**	..	**7,81,02,439**	**5,872,364**	..
Average .	..	..	*2 12 3*	..	..	*3 1 11*

TABLE 11.—*Origin of Indian Coal raised during the years 1936 and 1937.*

—	Average of last five years.	1936.	1937.
	Tons.	Tons.	Tons.
Gondwana coalfields	22,170,471	22,212,457	24,571,343
Tertiary coalfields	391,183	398,364	465,043
TOTAL .	**22,561,654**	**22,610,821**	**25,036,386**

TABLE 12.—*Output of Gondwana Coalfields during the years 1936 and 1937.*

—	1936. Tons.	1936. Per cent. of Indian total.	1937. Tons.	1937. Per cent of Indian total.
Bengal, Bihar and Orissa—				
Bokaro	1,417,227	6·27	2,309,170	9·22
Giridih	*698,133*	*3·09*	674,794	2·70
Jainti	36,022	0·16	47,490	0·19
Jharia	8,830,144	39·05	9,601,230	38·35
Karanpura	396,083	1·75	534,328	2·14
Rajmahal Hills	1,709	0·01	1,201	0·01
Rampur (Raigarh Hingir)	31,061	0·14	47,127	0·18
Raniganj	7,305,437	32·31	7,196,324	28·74
Central India—				
Sohagpur	249,633	1·10	251,035	1·00
Umaria	79,855	0·35	83,256	0·33
Central Provinces—				
Ballarpur	247,122	1·09	264,269	1·05
Pench Valley	1,259,133	5·57	1,234,233	4·93
Shahpur (Betul)	1,727	0·01	5,657	0·03
Eastern States Agency—				
Korea	580,143	2·57	850,701	3·39
Raigarh State	2,625	0·01	2,500	0·01
Talcher	223,661	0·99	391,787	1·56
Hyderabad—				
Kothagudium			1,176	0·01
Sasti	53,589	0·24	68,671	0·27
Singareni	606,107	2·68	740,770	2·96
Tandur	193,043	0·85	265,624	1·06
TOTAL	**22,212,457**	*98·24*	**24,571,343**	*98·13*

TABLE 13.—*Output of Tertiary Coalfields during the years 1936 and 1937.*

—	1936.		1937.	
	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.
Assam—				
Khasi and Jaintia Hills .	10,817	0·90	7,648	1·00
Makum and Lakhimpur .	172,075		218,488	
Naga Hills . . .	20,347		22,427	
Baluchistan—				
Khost	2,818	0·04	6,262	0·07
Sor Range, Mach, Kalat .	5,281		11,217	
Punjab—				
Jhelum	61,654	0·69	62,095	0·67
Mianwali	87,382		98,740	
Shahpur	7,813		5,797	
Rajputana—				
Bikaner	30,177	0·13	32,369	0·13
TOTAL .	**398,364**	*1·76*	**465,043**	*1·87*

The development of an iron and steel industry in India on modern lines has led to the erection of several plants for the manufacture of hard coke of metallurgical quality and it has therefore become a matter of general interest to know the proportion of the total annual output of coal in India that is utilised in the manufacture of hard coke. The figures for 1936 and 1937 are shown in Table 14.

TABLE 14.—*Quantity of Hard Coke produced in India during the years 1936 and 1937.*

—	1936.	1937.
	Tons.	Tons.
Coal used	2,366,728	2,637,652
Hard coke manufactured	1,811,291	1,866,853
Percentage recovery	*76·53*	*70·8*
Sources of coal used—		
Jharia field	2,233,886	2,472,182
Giridih field	37,570	72,240
Raniganj field	92,302	83,925
Bokaro field	..	6,777
Lakhimpur (Namdang) field	2,970	2,528
TOTAL	2,366,728	2,637,652
Coal used for coking by—		
Two iron and steel companies	1,915,577	2,164,486
Others	451,151	473,166

In opposition to the trend of 1934, 1935 and 1936, the exports of coal from India in 1937 have more than doubled as compared with 1936, deducting Burma's share. Since the separation of Burma on the 1st April, 1937, it appears in these statistics as a foreign country, and in 9 months has taken a little more than Ceylon did in the year.

TABLE 15.—*Exports to Foreign Countries of Indian Coal and Coke during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
To—	Tons.	Rs.	£	Tons.	Rs	£
Ceylon	148,597	13,08,496	98,383	379,024	35,75,579	268,841
Burma*	..	..	..	379,520	33,68,346	253,259
Straits Settlements	16 660	99,960	7,516	44,671	3,75,748	28,252
Hongkong	5,038	30,228	2,273	7,528	75,280	5,660
Other countries	25,541	1,81,619	13,656	45,382	4,19,618	31,550
TOTAL	195,836	16,20,303	121,828	856,125	78,14,571	587,562
Coke	1,376	24,331	1 829	17,185	3,25,411	24,467
Total of Coal and Coke	**197,212**	16,44,634	123,657	**873,310**	81,39,982	612,029

* From 1st April, 1937.

The following table gives the amounts of different grades of coal exported during 1936 and 1937 under the Indian Coal Grading Board's scheme (including sea-borne coal for railways in Southern India, for which no grade shipment certificates were issued by the Coal Grading Board) and shows an increase of 145,483 tons in the present year, the difference between the total amounts so exported (1,802,778 tons in 1937) and the total exports of Indian Coal to foreign ports given in Table 15 (873,310 tons in 1937) being the amount of coal exported to Indian ports.

TABLE 16.—*Exports of Coal under Grading Board Certificates during the years 1936 and 1937.*

	1936.	1937.
	Tons.	Tons.
Selected grade	1,601,057	1,702,181
Grade I	41,071	95,030
Grade II	14,956	3,074
Mixed grade	211	2,493
TOTAL	**1,657,295**	**1,802,778**

In reversal of the trend of previous years, imports of coal and coke showed increases during 1932 and 1933, namely from 47,544 tons in 1932 to 67,330 in 1933; 21,121 tons of the latter consisted of coke. 1934 showed a further slight increase to 72,161 tons, of which 14,719 tons were coke, and 1935 an increase to 77,075 tons, of which 12,791 tons were coke. In 1936 there was a further increase to 95,936 tons, of which 20,808 tons were coke but, in 1937, imports fell again to 64,850 tons, of which 3,305 tons were coke. The fall is chiefly due to the exclusion of coal imported into Burma during April to December. Imports of coal from the United Kingdom, however, rose by over 5,000 tons (*see* Table 17). The total imports are now about a seventh of those of the pre-war quinquennium and Table 18, comparing pre-war imports and exports with the figures from 1926 to 1937, shows that the depression in the Indian coal industry, which reached its maximum in 1933, cannot be ascribed to the competitive effect of foreign imported coal. The average surplus of exports during the years 1926 to 1935 was, in fact, slightly greater than the surplus during the pre-war quinquennium, and the increase in 1937 is great, even allowing for the figures for export to Burma, which, before separation, were not included as exports.

TABLE 17.—*Imports of Coal and Coke during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
From—						
Australia	4,598	97,650	7,342	2,751	61,962	4,659
United Kingdom . .	17,232	2,86,852	21,568	22,536	4,78,332	35,965
Union of South Africa . .	30,134	4,44,938	33,454	19,918	3,12,767	23,516
Other countries . . .	23,169	3,36,360	25,290	16,340	2,48,612	18,693
TOTAL .	75,128	11,65,800	87,654	61,545	11,01,673	82,833
Coke	20,808	4,48,102	33,692	3,305	1,11,680	8,397
Total of Coal and Coke .	95,936	16,13,902	121,346	64,850	12,13,353	91,230

TABLE 18.—*Excess of exports over imports of Coal.*

——	Exports.	Imports.	Excess of exports over imports.
	Tons.	Tons.	Tons.
Average for 1909-13	814,475	466,162	348,313
1926	617,563	193,908	423,655
1927	576,167	243,603	332,564
1928	626,343	210,186	416,157
1929	726,610	218,560	508,050
1930	461,188	217,029	244,159
1931	441,249	88,035	353,214
1932	519,483	47,544	471,939
1933	426,176	67,330	358,846
1934	330,233	72,161	258,072
1935	217,584	77,075	140,509
1936	197,212	95,936	101,276
1937	873,310	64,850	808,460

The average number of persons employed in the coalfields during the year showed an increase of 7·2 per cent. The average output per person employed showed a decrease from the high figure of 130·2 tons in 1934, which is practically the same as the figure for 1929, namely 130·4 tons, the highest figure recorded, to 128·59 tons in 1937. All the figures for the last eight years are higher than those previously recorded; these higher figures are due partly to an increased use of mechanical coal-cutters, and partly to concentration of work. During recent years a large number of collieries have been shut down and the labour absorbed in the remainder; this concentration permits of a proportional reduction of the supervising staff, resulting in a larger tonnage per head. There was a decrease in the number of deaths by accident from 274 in 1935, 435 in 1936, to 213 in 1937. In 1935 there were three major accidents, at Loyabad and Bagdigi collieries in the Jharia coal-

field and at Kurhurbaree colliery in the Giridih coalfield, in which 11, 19 and 62 lives, respectively, were lost; in 1936 there were two, at Poidih in the Raniganj field, and Loyabad in the Jharia field, which accounted for 209 and 35 deaths respectively. These figures may be compared with the annual average for the quinquennium 1919-1923, which was 274, the annual average for the quinquennium 1924-1928, which was 218, and the annual average for 1929-1933, which was 186. The death rate was 1·09 per thousand persons employed in 1937; the average figure for the period 1919-1923 was 1·36, for the period 1924-1928 was 1·16, and for the period 1929-1933 was 1·08.

TABLE 19.—*Average number of persons employed daily in the Indian Coalfields during the years 1936 and 1937.*

——	1936.	1937.	Output per person employed, in tons.	Number of deaths by accident.	Death rate per 1,000 persons employed.
Assam	2,165	2,091	118·87	5	2·39
Baluchistan	177	393	44·48	..	..
Bengal	51,061	51,077	127·80	58	1·13
Bihar	94,553	103,195	134·08	111	1·08
Central India	2,794	2,571	130·02	4	1·51
Central Provinces	12,731	11,918	126·21	19	1·58
Eastern States Agency	6,174	8,279	150·38	..	..
Hyderabad	9,486	12,308	87·44	9	0·74
Orissa	197	322	146·36	1	3·11
Punjab	2,208	2,399	69·46	6	2·50
Rajputana	141	152	212·95	..	..
TOTAL	**181,687**	**194,705**	..	**213**	..
Average	..	..	*128·59*	..	*1·09*

Cobalt.

The nickel speiss from the Namtu smelter of the Burma Corporation, Limited, contains 6·81 per cent. of cobalt. In 1937, 4,020 tons of the speiss were produced. (*See* Nickel, p. 345.)

Copper.

The progress of work at the Mosaboni Mine of the Indian Copper Corporation, Ltd., in the Singhbhum district, and on the milling and smelting plant at Maubhandar, near Ghatsila, Bengal Nagpur Railway, has been noticed in previous Reviews. Operations commenced on a revenue basis on January 1st, 1929, and the progress of the industry until 1933 is summarised in the Quinquennial Review for 1929-1933. Together with an improvement in market price the production of both mine and smelter has continued to expand. In addition, from 1933 onwards, there has been production of ore from Dhobani, where a lode parallel to that at Mosaboni is being opened up. During 1937 operations extended to five mines and the total output of ore increased to 371,458 long tons valued at Rs. 48,69,790 (£366,150) as compared with 357,194 long tons valued at Rs. 40,03,200 (£300,993) in 1936. The total output was obtained as follows :—

	Long tons.
Mosaboni	335,859
Dhobani	30,986
Badia	4,012
Surda	601
	371,458

A total of 374,782 short tons of ore was treated in the mill, at a valuation of Rs. 47,34,666, and the production of refined copper amounted to 6,830 long tons against 7,200 long tons in the previous year. A total of 6,422 tons of copper ingots was consumed in the rolling mill and 270 tons were sold in the Indian market at an average price of Rs. 903 per ton *f.o.r.* Ghatsila. Operations in the rolling mill resulted in the production of 8,696 long tons of yellow metal sheet (of which 92 tons were utilised for conversion into circles) and 1,323 long tons of yellow metal circles, the whole of which was sold in India at average prices of Rs. 765 and Rs. 821 respectively per ton.

The total ore reserves at the close of the year 1937 amounted to 946,000 short tons, with an average assay value of 2·91 per cent. of copper, against 949,175 short tons, with an average assay value of 2·97 per cent. of copper, at the end of 1936. The Indian Copper Corporation reached the dividend paying stage in 1933.

An output of 115 tons of copper ore, valued at Rs. 1,725 (£130), is reported from Mysore.

There was an increase in the production of copper matte at the Namtu smelting plant of the Burma Corporation, Limited, from 7,500 tons valued at Rs. 20,09,978 (£151,126) in 1936 to 7,750 tons valued at Rs. 24,18.465 (£181,839) in 1937, and averaging 42·74 per cent. of copper, 25·98 per cent. of lead and 70·55 ozs. of silver to the ton. Included in the ore-reserves in the Bawdwin mine of the Burma Corporation are approximately 275,000 tons of copper ore.

Diamonds.

The production of diamonds in Central India fell from 1,457 carats valued at Rs. 62,171 (£4,675) in 1936 to 1,178 carats valued at Rs. 54,979 (£4,134) in 1937. Of this latter production 1,054 carats were produced in Panna State and the remainder in Charkhari and Ajaigarh States.

Gold.

In 1931 the gradual secular decline in the total Indian gold production was temporarily arrested with an output of 330,488·8 ozs. valued at Rs. 2,08,01,943 (£1,540,885), followed by a trivial fall again in 1932, when the output was 329,681·7 ozs. valued at Rs. 2,53,51,438 (£1,906,123). In 1933 there was an increase to 336,108·3 ozs. valued at Rs. 2,76,40,071 (£2,078,201). In 1934 the output fell to 322,142·9 ozs., but the value increased to Rs. 2,92,71,130 (£2,200,836). It is interesting to note that the output of 1921, which was valued at £2,050,575, a figure very close to that of the 1933 production, was 432,722·6 ozs. In 1935 the output rose again to 327,652·5 ozs. valued at Rs. 3,04,01,775 (£2,285,848), and in 1936 to 333,385·6 ozs. valued at Rs. 3,06,02,413 (£2,300,933). In 1937 the output fell slightly to 331,748·2 ozs., valued at Rs. 3,04,80,105 (£2,291,737).

All fields shared in this decrease, except for the insignificant production of 1·9 ozs. from the United Provinces. The Burma

output decreased considerably, owing principally to a fall in production from 1,294 ozs. to 894 ozs., from the operations of the Burma Corporation in the Northern Shan States. But these figures are, of course, quite insignificant compared with the output of Kolar, which makes up 99·6 per cent. of the India and Burma total. The considerable increase in the value of the production in 1932 was due to that being the first full year since Britain and India abandoned the gold standard in September, 1931, with consequent appreciation in the price of gold against sterling or rupees. As a result of this appreciation, 9,766,122 ozs. of gold reckoned in terms of fine gold were exported during 1932. The value was Rs. 75,87,52,203 (£57,049,038). In 1933 the exports were 6,248,095 ozs. valued at Rs. 51,25,48,810 (£38,537,505), in 1934 they were 6,685,900 ozs. valued at Rs. 60,50,74,489 (£45,494,323), in 1935, 4,732,185 ozs. valued at Rs. 44,22,27,875 (£33,250,216), in 1936, 3,588,117 ozs. valued at Rs. 33,15,99,305 (£24,932,279), and in 1937, 1,971,126 ozs. valued at Rs. 18,27,80,654 (£13,742,906).

Of the four mines that are producing gold in the Kolar Gold Field, the Champion Reef and the Ooregum Mines, the two deepest on the field, reached vertical depths of 7,960 feet and 8,224 feet respectively below field datum (2,967·21 feet above Madras sea-level) on the 31st December, 1937. The development in depth has disclosed the continuity of the reef, and a number of shoots of payable ore have been opened up. At these depths the dip of the reef is almost vertical. The ore is not refractory and yields its gold to blanket concentration and cyaniding; 'all-sliming' practice is becoming general. The concentrates are pan- or plate-amalgamated. The rock temperature at the deepest working place was 133°F. Owing to the great depths of these mines and the consequent high temperatures, the maintenance of adequate ventilation at the working places is an extremely complex problem, and it has been partly solved by sinking deep, smooth-lined vertical shafts, circular or elliptical, and by an extensive use of large electrically-driven fans in the course of the main air currents. The subsidiary shafts and winzes in the lower levels are brick- or concrete-lined and as such assist the free movement of air by reducing friction to a minimum. Though rock-bursts cannot be eliminated altogether in deep mining, the more rigid forms of support, such as packs of masonry and concrete, and sand or waste rock filling, which are generally used in these mines, have resulted in the reduc-

tion of the number of heavier rock-bursts, which were causing considerable damage to person and property in the past.

The average number of persons employed on the Kolar Gold Field during 1937 was 23,881, of whom 15,304 worked underground.

TABLE 20.—*Quantity and value of Gold*[1] *produced in India and Burma during the years 1936 and 1937.*

	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Ozs.	Rs.	£	Ozs.	Rs.	£
India—						
Bihar	82·0	5,004	376	26·0	1,645	124
Mysore . . .	331,856·1	3,04,92,796	2,292,691	330,710·2	3,03,93,539	2,285,229
Punjab . . .	7·0	512	39	5·8	537	40
United Provinces . .	1·1	97	7	1·9	150	11
TOTAL .	331,946·2	3,04,98,409	2,293,113	330,743·9	3,03,95,871	2,285,404
Burma—						
Katha . . .	58·0	4,131	311	31·1	3,005	226
Upper Chindwin . .	87·4	10,478	788	79·2	9,483	713
Northern Shan States .	1,294·0	89,395	6,721	894·0	71,746	5,394
TOTAL .	**1,439·4**	*1,04,004*	*7,820*	**1,004·3**	*84,234*	*6,333*

[1] Fine ounces in the case of Mysore.

Ilmenite.

There was a large increase in the production of ilmenite in Travancore State from 75,644 tons valued at £39,245[1] in 1934 to 127,051 tons valued at £58,789 in 1935, to 140,477 tons valued at £62,418 in 1936, and again to 181,047 tons, valued at Rs. 11,26,329

[1] Revised value,

(£84,686) in 1937, this being the highest output yet recorded. Since 1927 India has been the world's largest producer of ilmenite. This mineral occurs in the monazite sands and, up to a few years ago, was looked upon as a by-product of the monazite industry. The monazite sands have been worked continuously since 1911, but it was not until 1922 that the export of ilmenite commenced, since when the production of the mineral has expanded almost continuously, so that in both quantity and value the production of ilmenite is now much more important than that of the associated minerals monazite and zircon. This steady increase in the output of ilmenite is due to the demand for its content of titanium dioxide in the manufacture of titanium paints. The exports of ilmenite were 106,585 tons in 1935, 123,799 tons in 1936 and 204,653 tons in 1937.

Iron.

For some years up to and including 1929 the production of iron-ore in India had been steadily increasing; India is now, in fact, the second largest producer in the British Empire, and yields place only to the United Kingdom. Her output is of course still completely dwarfed by the production in the United States (30½ million tons in 1935 and 48¾ million tons in 1936) and France (32·3 million tons in both 1935 and 1936); but her reserves of ore are not much less than three-quarters of the estimated total in the United States and there is every hope that India will eventually take a much more important place among the world's producers of iron-ore. From 2,430,136 tons in 1929 the output of iron-ore in India fell to 1,228,625 tons in 1933. In 1934, however, there was a turn of the tide and the production recovered sharply to 1,916,918 tons, and in 1935 rose still further to 2,364,297 tons, in 1936 to 2,553,247 tons, and in 1937, to 2,896,258 tons valued at Rs. 46,88,082 (£352,487). As in former years, these figures include the output of about 25,000 tons, by the Burma Corporation, which is used as a flux in lead-smelting. As will be seen later, there were also substantial increases in the output of pig-iron and steel. The figures shown against the Keonjhar and Mayurbhanj States in Table 21 represent the production by Bird & Co., and the Tata Iron and Steel Co., Ltd., respectively. Of the total production of 1,587,362 tons shown against Singhbhum, 681,157 tons were produced by the

Tata Iron and Steel Co., Ltd., 901,124 tons by the Indian Iron and Steel Co., Ltd., and the remaining 5,081 tons by small concerns.

TABLE 21.—*Quantity and value of Iron-ore produced in India and Burma during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
India—						
Bihar-						
Singhbhum .	1,375,214	22,22,580	167,111	1,587,362	27,30,077	205,269
Central Provinces . .	549	1,646	124	354	1,062	80
Eastern States Agency-						
Keonjhar State . .	259,819	2,59,819	19,535	307,935	3,18,646	23,958
Mayurbhanj State .	849,412	12,92,063	97,193	942,701	14,31,760	107,651
Mysore State . .	41,937	1,35,162	10,162	32,480	1,04,833	7,882
TOTAL	**2,526,931**	*39,11,870*	*294,125*	**2,870,832**	*45,86,378*	*344,840*
Burma—						
Northern Shan States .	26,316	(*a*) 1,05,264	7,915	25,426	(*a*) 1,01,704	7,647

(*a*) Estimated.

The production of pig-iron by the Tata Iron and Steel Co., at Jamshedpur rose from 858,272 tons in 1936 to 885,393 tons in 1937, while their steel production rose from 660,291 tons in 1936 to 665,309 tons in 1937. The production of ferro-manganese rose from 3,263 tons in 1936 to 8,041 tons in 1937.

TABLE 22.—*Production of Pig-iron by the Tata Iron and Steel Company, Limited, during 1936 and 1937.*

——	1936.	1937.
	Tons.	Tons.
Pig-iron for Duplex Plant Bessemer Convertors . .	621,684	653,024
,, for Open Hearth	135,039	148,578
,, for sale and use in foundries . . .	87,338	69,497
Molten pig used for direct castings	14,211	14,294
TOTAL .	858,272	885,393

The pig-iron is graded as follows :—

(*a*) Standard Foundry Nos. 1, 2, 3 and 4.
(*b*) Special No. 4X.
(*c*) Special Basic.
(*d*) Standard Basic.
(*e*) Low manganese Foundry Nos. 1, 2, 3, 4 and 4X.
(*f*) Low manganese Basic special.
(*g*) Low maganese Basic.
(*h*) High manganese Basic.

During 1936 the Indian Iron and Steel Co. and the Bengal Iron Co. amalgamated and the output of pig-iron by the combined company increased from 659,543 tons in 1936 to 713,030 tons in 1937.

TABLE 23.—*Production of Pig-iron by the Indian Iron and Steel Company, Limited, during 1936 and 1937.*

——	1936.	1937.
	Tons.	Tons.
Foundry	464,140	492,929
Basic quality	195,062	214,278
Spiegeleisen	341	327
High Silicon	..	5,496
TOTAL .	659,543	713,030

60,275 tons of iron castings were produced in 1937 by the Indian Iron and Steel Co.

The output of charcoal pig-iron by the Mysore Iron and Steel Works rose slightly from 22.241 tons in 1936 to 22,837 tons in 1937.

The total production of pig-iron in India rose from 1,540,056 tons in 1936 to 1,621,260 tons in 1937, and is shown in Table 24.

TABLE 24.—*Production of Pig-iron in India during the years 1936 and 1937.*

	1936.	1937.
	Tons.	Tons.
The Tata Iron and Steel Company, Limited . .	858,272	885,393
The Indian Iron and Steel Company, Limited . .	659,543	713,030
The Mysore Iron and Steel Works	22,241	22,837
TOTAL .	1,540,056	1,621,560

The total number of indigenous furnaces that were at work in the Central Provinces during the year 1937 for the purpose of smelting iron-ore was 110 against 92 in the previous year; 59 furnaces were operating in the Bilaspur district, 38 in Mandla, 3 in Raipur, 4 in Chanda, and 6 in Drug.

The increase in the production of pig-iron in India recorded above was accompanied by a slight fall in the quantity exported, from 605.976 tons in 1936 to 597.331 tons in 1937. The value, however, increased by about half. Table 25 shows that Japan is still the principal consumer of Indian pig-iron though the quantity taken fell by 85.548 tons, 23·3 per cent.; the proportion taken fell from 70·8 per cent. in 1935 to 60·6 per cent. in 1936 and 47·2 per cent. in 1937. There were large increases in exports to the United Kingdom, which took 36·1 per cent. of the exports, and smaller increases to the United States, China and other countries. The export value per ton of pig-iron rose from Rs. 22·6 (£1·70) in 1936 to Rs. 34·5 (£2·6) in 1937.

The Steel Industry (Protection) Act, 1924 (Act No. XIV of 1924) authorised, to companies employing Indians, bounties upon rails and fishplates wholly manufactured in British India from materials wholly or mainly produced from Indian iron-ore and

complying with specifications approved by the Railway Board, and upon iron or steel railway wagons, a substantial portion of the component parts of which had been manufactured in British India. This Act was repealed by the Act No. III of 1927 and the payment of bounties consequently ceased on the 31st March, 1927; the industry is, however, protected to a certain extent by the varying tariffs on different classes of imported steel. As a result of a new Act, No. XXXI of 1934, provision has been made for an increase of tariffs by about half over the 1927 rates, or about Rs. 10 per ton *ad valorem* in most cases, or about Rs. 40 per ton in the case of articles not of British manufacture.

TABLE 25.—*Exports of Pig-iron from India during the years 1936 and 1937.*

----	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
China	5,749	1,33,160	10,012	6,766	1,81,528	13,649
Japan	367,296	83,30,307	626,339	281,748	95,53,412	718,302
United Kingdom . .	160,571	35,49,020	266,843	215,801	77,13,868	579,990
United States of America	56,244	12,92,289	97,165	68,013	23,85,623	179,370
Other Countries . .	16,116	4,03,288	30,322	25,003	7,64,147	57,454
TOTAL .	605,976	*1,37,08,064*	*1,030,681*	597,331	*2,05,98,578*	*1,548,765*

Jadeite.

There was an increase in the output of jadeite from the Myitkyina district, Burma, which rose from 1,671 cwts., valued at Rs. 1,78,374 (£13,412), to 2,952 cwts. valued at Rs. 1,73,304 (£13,030) in 1937, a fall in value. Exports by sea rose from 1,445 cwts., valued at Rs. 86,321 (£6,490) in 1936 to 2,410 cwts., valued at Rs. 1,28,912 (£9,693) in 1937. These shipments were entirely from Burma.

Lead.

The production of lead-ore at the Burma Corporation's Bawdwin mines in Burma rose slightly from 468,842 tons in 1936, to 476,896 tons, valued at Rs. 1,28,24,215 (£964,227), in 1937, whilst the total amount of metal extracted rose slightly from 73,155 tons (including 1,240 tons of antimonial lead) valued at Rs. 1,72,27,460 (£1,295,298) in 1936, to 77,650 tons (including 1,150 tons of antimonial lead) valued at Rs. 2,43,83,836 (£1,833,371) in 1937. The quantity of silver extracted from the Bawdwin ores rose slightly from 5,952,000 ozs., valued at Rs. 68,71,584 (£516,660) in 1936 to 6,180,000 ozs., valued at Rs. 73,60,998 (£553,458) in 1937. The value of the lead per ton rose from Rs. 235·5 (£17·71) to Rs. 318·7 (£23·96) whilst the value of the silver per ounce rose from Re. 1-2-6 (20·8*d.*) to Re. 1-3-1 (21·49*d.*) in the year under review. The ore reserves in the Bawdwin mine as calculated on the 30th of June, 1937, totalled 3,863,548 tons against 3,914,182[1] tons at the end of June, 1936, with an average composition of 23·3 per cent. of lead, 14·6 per cent. of zinc, 0·95 per cent. of copper, and 23·3 ozs. of silver per ton of lead. (*See* Copper, p. 330.)

Magnesite.

The output of magnesite from Salem district almost doubled, with a decrease of 118 tons from Mysore State.

TABLE 26.—*Quantity and value of Magnesite produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Madras—						
Salem	12,966	77,248	5,808	23,782	1,40,708	10,580
Mysore State . . .	2,502	24,948	1,876	2,384	23,230	1,746
TOTAL .	**15,468**	*1,02,196*	*7,684*	**26,166**	*1,63,938*	*12,326*

[1] Revised figure.

Manganese.

The catastrophic fall in the production of manganese-ore in India from the peak figures of 1927, namely 1,129,353 tons valued at £2,703,068 *f.o.b.* Indian ports, to 212,604 tons with a value of £140,022 in 1932 has been recorded in previous Reviews. In 1933 the output rose slightly to 218,307 tons but the value fell to £123,171. These are the smallest quantities and values reported since 1901, when the output was 120,891 tons valued at £122,831. In 1905 the output was 247,427 tons valued at £223,432, since when the smallest production was 450,416 tons in 1915 valued at £929,546; whilst the smallest value was in 1909 when a production of 644,660 tons was valued at £603,908. In 1934 there was, however, a partial recovery to 406,306 tons valued at £388,240, further increased in 1935 to 641,483 tons valued at £768,630, in 1936 to 813,442 tons valued at £1,124,422 and in 1937 to 1,051,594 tons valued at £3,229,554. The full magnitude of this catastrophe to the Indian manganese industry is perhaps best realised from the fact that whilst the quantity of the production in 1933 was a little over one-fifth of that of the peak year of 1927, the value was less than one-twenty-second part of the value of the 1927 production. In fact in none of the major Indian mineral industries had the effects of the slump been so seriously felt as in the manganese industry; it is gratifying therefore, that a recovery can now be recorded to almost the peak output of 1927, with a much higher value.

The recovery in 1936 has been continued by substantial increases in the Balaghat, Nagpur and Bhandara districts of the Central Provinces, and in the Sandur State. The most pleasing feature of this improvement is the recovery of the Central Provinces production from the trivial figure to which it had fallen in 1933 (28,789 tons) to 695,177 tons in 1937. During 1932 and 1933 the majority of mines in the Central Provinces had been closed, including several mines that had never been closed since the commencement of work in 1900 and 1901; there had been a total cessation of production in the Nagpur district and almost total cessation in Bhandara. The amount of ground recovered can be judged from the fact that the production of the Central Provinces averaged 660,559 tons annually during the quinquennium 1924 to 1928. All producing districts participated in the increase, except Bonai State, the output of which is unimportant.

The fall in the Indian output of manganese-ore of recent years can be correlated with the fall in the price of first-grade ore, *c.i.f.* United Kingdom ports, from an average of 22·9*d*. per unit in 1924 to 14·9*d*. per unit in 1929, and then to 9·5*d*. per unit in 1932 and 1933, whilst the partial recovery in output in 1934 accompanied a rise in the average price to 10·5*d*. per unit, to 12·26*d*. in 1936, and to 22·5*d*. in 1937.

This continued fall in the price of manganese-ore from 1924 to 1932 is to be correlated with the fact that from 1924 to 1927 the rate of increase of the world's production of manganese-ore was much greater than the rate of increase in the world's production of pig-iron and steel. And although there was a fall in the world's output of manganese-ore in 1928, there was a very large increase in 1929, greater than was justified by the increased production of iron and steel in that year, and it is evident that the world's available supplies of manganese-ore are now much in excess of normal requirements. Russia is able to place large quantities of ore on the market at a price with which many Indian producers cannot compete without a return to pre-war railway freights. The Gold Coast has also become a serious competitor of recent years. The large deposits of high-grade manganese-ore discovered near Postmasburg in South Africa are also being developed. With this increasing competition and falling prices it is not surprising, therefore, that in spite of the apparent prosperity of the Indian manganese industry in 1929 and 1930, as judged from figures of production and export, yet by 1930 the industry as a whole had arrived at a stage of relative depression, causing many operators to cease work. Added to increased available supplies there was in 1931 and 1932 the disastrous decline in the activities of the iron and steel industry of the world, illustrated by a decline from the peak figure of 122 million tons of steel in 1929 to about 68 million tons in 1931 and only 42 million tons in 1932. In 1933 there was partial revival and the output of steel was some 56·4 million tons rising to about 68 million tons in 1934, 82·3 million tons in 1935, 103 million tons in 1936, and 111·9 million tons (estimated) in 1937. This partial recovery in the steel industry resulted in the hardening in the price of manganese-ore from 1934 to 1936 recorded in the preceding paragraph.

The present chief sources of production of manganese-ore are Russia, India, the Gold Coast, South Africa, Brazil, Cuba, Egypt, Czechoslovakia and Japan.

There is a steady consumption of manganese-ore at the works of the two principal Indian iron and steel companies, not only for use in the steel furnaces of the Tata Iron and Steel Company, and for the manufacture of ferro-manganese, but also for addition to the blast-furnace charge in the manufacture of pig-iron. The consumption of manganese-ore by the Indian iron and steel industry in the year under review amounted to 60,219 tons against 46,221 tons in 1936.

TABLE 27.—*Quantity and value of Manganese-ore produced in India during the years 1936 and 1937.*

——	1936.		1937.	
	Quantity.	Value f.o.b. at Indian. ports.	Quantity.	Value f.o.b. at Indian ports.
	Tons.	£	Tons.	£
Bihar—				
Singhbhum	11,722	17,437	24,180	77,376
Bombay—				
North Kanara	..	..	18,723	59,914
Panch Mahals	28,994	43,129	41,041	131,331
Central Provinces—				
Balaghat	313,933	498,368	399,532	1,353,414
Bhandara	134,710	213,852	153,230	519,066
Chhindwara	803	1,274	1,048	3,530
Nagpur	119,360	189,484	141,367	478,880
Eastern States Agency—				
Bonai	15,921	15,324	13,856	35,217
Keonjhar	68,116	58,801	82,128	208,742
Madras including Madras States—				
Bellary	100	71	450	913
Kurnool	..	..	200	423
Sandur State	102,966	73,363	149,782	303,933
Vizagapatam	15,258	12,143	20,509	45,120
Mysore—				
Chitaldrug	692	522	2,841	5,993
Shimoga	769	580	2,207	4,044
Tumkur	98	74	500	1,058
TOTAL	**813,442**	***1,124,422***	**1,051,594**	***3,229,554***

The partial recovery of the Indian manganese industry during 1934 and 1935 was reflected in an increase of exports, including the quantities exported from Mormugao in Portuguese India, from the nadir of 375,904 tons in 1933 to 864,698 tons in 1935. In 1936 this fell to 742,547 tons, but rose to 1,151,834 tons in 1937. Table 29 shows the distribution of manganese-ore exported from British Indian ports (excluding Mormugao) during 1936 and 1937, from which it will be seen that the United Kingdom with an increase of some 53,000 tons retained her position as the chief importer of Indian manganese-ore. The second place as importer was taken by France with an increase of some 92,000 tons, with Japan as third with an increase of some 70,000 tons; Belgium showed an increase of 75,000 tons and the United States 34,000 tons.

TABLE 28.—*Exports of Manganese-ore during 1936 and 1937 according to ports of shipment.*

——	1936.	1937.
	Tons.	Tons.
Bombay	92,832	130,837
Calcutta	250,216	316,767
Vizagapatam	290,775	533,585
Mormugao (Portuguese India)	108,524	170,645
TOTAL	**742,347**	**1,151,834**

TABLE 29.—*Exports of Manganese-ore from British Indian ports during the years 1936 and 1937.*

	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
To						
United Kingdom . .	219,041	44,34,761	..	272,265	57,72,092	433,992
Germany . . .	12,617	3,69,046	..	17,935	4,77,858	35,920
Netherlands . .	5,750	1,03,500	..	18,412	3,45,497	25,977
Belgium . . .	62,015	12,78,214	..	137,537	32,13,962	241,651
France . . .	93,346	17,65,760	132,764	185,203	42,09,414	316,497
Italy . . .	1,000	16,375	1,231	10,564	2,61,417	19,655
Japan	108,374	16,41,594	123,428	178,547	32,80,694	246,669
United States of America	109,102	20,97,958	157,741	143,102	29,07,982	218,645
Other countries . .	22,578	4,32,602	..	17,624	3,70,150	27,832
TOTAL .	**633,823**	*1,21,40,710*	..	**981,189**	*2,08,39,066*	*1,566,847*

Mica.

There was a rise in the declared production of mica from 87,071 cwts. valued at Rs. 32,52,350 (£244,538) in 1936 to 104,478 cwts., valued at Rs. 39,50,281 (£297,014) in 1937. As has been frequently pointed out the output figures are incomplete and a more accurate idea of the size of the industry is to be obtained from the export figures. (Table 31.)

The difference between exports and production has generally been attributed to theft from the mines, but the production recorded is for dressed mica only, whereas the exports include, as well as this, much material recovered from dumps, splittings and waste mica, and mica won in *Zamindaries* and in prospecting. This, as well as stolen mica, makes up the discrepancy.

The United States of America and the United Kingdom, which are the principal importers of Indian mica, absorbed respectively 51·8 per cent. and 24·2 per cent. during 1936, and 62·3 per cent. and 22·1 per cent. during 1937. Germany took 10·7 per cent. and

6·3 per cent. respectively, of the total quantities exported during the years 1936 and 1937. The average value of the exported mica decreased from Rs. 51·7 (£3·9) per cwt. in 1936 to Rs. 48·3 (£3·6) in 1937. The exports rose from 177,664 cwts. valued at Rs. 91,76,511 (£689,963) in 1936 to 297,343 cwts., valued at Rs. 1,43,60,036 (£1,079,702) in 1937.

TABLE 30.—*Quantity and value of Mica produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity	Value (£1 = Rs. 13·3).	
	Cwts.	Rs.	£	Cwts	Rs.	£
Bihar—						
Bhagalpur . . .	13	195	15	922	6,646	500
Gaya . . .	18,792	6,81,616	51,249	20,055	7,32,788	55,097
Hazaribagh . . .	52,348	20,02,882	150,593	61,108	23,32,718	1,75,392
Manbhum	148	1,762	132	246	7,178	540
Monghyr	437	13,692	1,029	3,467	91,603	6,885
Gwalior	..	..	..	12	(a)	..
Madras including Madras States—						
Nellore	(b)13 609	4,99,290	37 541	(c)15 617	6,48,075	48,727
Nilgiris	80	10,181	765	120	16,017	1,204
Travancore State . .	53	1,500	113	67	2,150	162
Mysore	..	..	..	20	600	45
Rajputana—						
Ajmer-Merwara . . .	(d)1,496*	33,018	2,483	(e)2,034	87,513	6,580
Jaipur State . . .	95	8,214	618	780	24,093	1,879
TOTAL .	**87,071**	*32,52,350*	*244,538*	**104,478**	*39,50,281*	*297,014*

(a) Not reported.
(b) Excludes 10,714 cwts. of waste mica useful for splittings.
(c) Excludes 28,119 cwts. of waste mica useful for splittings.
(d) Excludes 1,858 cwts. of waste mica useful for splittings.
(e) Excludes 663 cwts. of waste mica useful for splittings.
*Revised.

TABLE 31.—*Quantity and value of Mica including splittings exported from India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
To—	Cwts.	Rs.	£	Cwts.	Rs.	£
United Kingdom	43,049	43,60,558	327,861	65,784	64,93,335	488,221
Germany	10,053	7,87,952	59,244	18,864	10,79,055	81,132
France	7,743	3,74,845	28,184	2,698	2,06,555	15,530
Japan	9,125	5,75,736	43,289	11,815	12,55,366	94,388
United States of America	93,080	27,90,668	209,825	185,143	43,67,799	328,406
Other countries	5,614	2,86,752	21,560	13,049	9,57,926	72,025
TOTAL	177,664	*91,76,511*	*689,963*	297,343	*1,43,60,036*	*1,079,702*

Monazite.

In its early years the monazite industry of Travancore State was of some importance and the output during the quinquennium 1914-1918 averaged annually 1,528 tons valued at £45,334. This prosperity continued only to 1921 and by 1925 the industry was moribund, with a production of 1 cwt. only. There has since been a revival and the output for the period 1929-1933 averaged annually 215 tons valued at £2,114. In 1934 the output was 1,009 tons valued at £3,769, which rose to 3,819 tons valued at £12,453 in 1935 but fell again to 2,628 tons valued at £8,116 in 1936, rising to 3,081 tons valued at Rs. 1,40,365 (£10,554) in 1937. The decline of the industry from the high figures of 1914 to 1921 is of course due to the supplanting of incandescent mantles for gas lighting by electricity. The partial revival of the monazite industry is presumably due to the greatly increased output of ilmenite, the production of monazite as a bye-product rendering cheaper production possible. 3,757 tons were exported in 1937, against 1,936 tons in 1936 and 3,954 tons in 1935.

Nickel.

As a bye-product in the smelting operations of the Burma Corporation, Limited, at Namtu, in the Northern Shan States, there is now a regular production of nickel-speiss, which, during the quinquennium 1929-1933 averaged annually 3,211 tons valued at Rs. 8,19,023 (£61,197). In 1933 the output was 3,350 tons, valued

at Rs. 10,28,523 (£77,333), which rose in 1934 to 3,951 tons valued at Rs. 11,44,337 (£86,401) and in 1935 to 4,850 tons, valued at Rs. 14,00,074 (£105,269). In 1936 the output was 4,325 tons valued at Rs. 14,82,809 (£111,489) and in 1937 was 4,020 tons valued at Rs. 13,91,049 (£104,590) the composition being 30·20 per cent. of nickel, 8·94 per cent. of copper, 6·81 per cent. of cobalt, and 17·7 ozs. of silver to the ton. The speiss is shipped to Hamburg for further treatment.

Petroleum.

The world's production of petroleum in 1926 amounted to nearly 150 million long tons, of which India contributed 0·72 per cent. In 1927, this figure jumped to some 172 million long tons, of which the Indian proportion, on a practically stationary production, fell to 0·64 per cent. In 1928, there was another substantial rise in the world's production, which reached the figure of over 181 million tons. In 1929, there was another jump to over 202 million tons, but in 1930 the world's production fell to about 193½ million tons, in 1931 to about 187 million tons, and in 1932 to about 183 million tons, whilst in 1933 the production rose again to about 202 million tons, in 1934 to about 215 million tons, in 1935 to 233 million tons, in 1936 to 248·8 million tons (revised figure) and in 1937 to 284 million tons (estimated).[1] Decreases were shown by Poland and Roumania. All other important producers showed an increase in production. The United States contributed 62·7 per cent. of the world's supply in 1937, Russia 9·9 per cent., Venezuela 9·2 per cent., Iran 3·8 per cent., Netherlands Indies 2·6 per cent. and Roumania 2·5 per cent. In 1928, India contributed 0·64 per cent., which fell to 0·60 per cent. in 1929 and rose to 0·62 per cent. in 1930, 0·63 per cent. in 1931, and 0·64 per cent. in 1932, and fell again to 0·62 per cent. in 1933, to 0·60 per cent. in 1934 and to 0·50 per cent. in 1935, 1936 and 1937, of which Burma contributed 0·40 and India proper 0·10 per cent.; her position on the list of petroleum producing countries fell from 11th in 1929 to 12th in 1930 to 1933, her place being taken by Trinidad, and to 13th in 1934, 1935, 1936 and 1937, due to the production by Iraq.

The production of petroleum in India (including Burma) increased from 334,811,624 gallons in 1936, to 350,322,222 gallons in 1937, the highest figure in the history of the industry. The increase in

[1] Compiled from *World Petroleum* of June, 1938.

1937 is due to an increase of some 20 million gallons from Singu, 5½ million gallons from Attock, 1¼ million gallons from Thayetmyo, and 1 million gallons from Digboi, accompanied by decreases of 9½ million gallons from Yenangyaung and 2 million gallons from Yenangyat.

The amount of gasolene produced from natural gas during the year was 10,616,313 gallons in Burma and 456,780 gallons in the Punjab.

The Yenangyaung field maintained its reputation of being one of the most wonderful oilfields in the world. The total production during 1937 was less than in the previous year but the resources of the field as a whole are sufficient to ensure an adequate supply of oil for many years.

At the end of 1937 there were 2,910 wells producing in the field. Besides a large number of wells drilled to shallow sands, this total includes 180 hand-dug wells, whose continued existence is one of the interesting features of the field.

During the year the deep drilling activities of 1936 in the southern part of the field died down, owing to the disappointing results obtained. On the eastern flank the limit of present economic extension of the oil-sands was approximately demarcated.

Satisfactory results continue to be obtained from gas drives in the leased blocks; in addition to gas drives, gas is also injected with the object of repressuring and storage. Casing policies continue to be carefully designed to protect the oil-sands against the danger of flooding by water and, in general, production methods throughout the field are characterised by a realisation of the importance of the conservation of oil and gas and the prevention of waste, whether simple or underground.

In 1937 the increase in the output from the Singu field was continued. This increased production was due not only to the rapid development of the valuable area in the southern part of the field but also to the successful results obtained from the first wells to produce from behind the practically completed river training wall of the Burmah Oil Company. At the end of the year the total number of producing wells was 568 as compared with 480 in December, 1936. In addition, a number of wells remained cemented above productive sands. These wells can be drilled into productive sands in a very short time and the total field production substantially increased.

There has been no radical change in production methods during the year under report. The fundamental principle underlying the policy of the major operating company at Singu is to make those adjustments at each well which lead to a maximum oil recovery with a minimum production of gas. Wells with high gas-oil ratios are shut in, and the balance of casing-head gas remaining after the satisfaction of the field requirements is returned to dry gas sands for storage, or to certain areas for repressuring purposes. The repressuring operations of the British Burmah Petroleum Company, Ltd., continued to give satisfactory results. The dry gas produced from the new gasoline extraction plant is used either in connection with these schemes or as fuel. Continuous gas lift on some wells producing from lower division sands and gas displacement pumping on wells producing from upper division sands were continued on a small scale, but production from the great majority of the wells in the field was obtained by ordinary pumping methods.

Although during 1937 active development continued at Yenangyat, the results obtained were somewhat disappointing and a decline in the total production from the Pakokku district, excluding Lanywa, was reported. Because of the large new production obtained from the Singu field, the production from the Lanywa field during 1937 was still further restricted. An inclined well was commenced during the year to tap the known oil sands beneath the Irrawaddy river. Back pressures are maintained on nearly all the wells in this model field, which is operated by the Indo-Burma Petroleum Company, Ltd. While a number of wells are pumped from a central power, the majority have individual pumping motors. The gasoline plant was operated throughout the year and gave a satisfactory yield.

In the Minbu district there were, at the close of the year, 374 producing wells. The total production showed little change. Apart from routine production there was very little activity in the district during the year.

There was a welcome increase during 1937 in the total production from the Indaw field. All producing wells were successfully operated by the automatic gas lift system.

In the Thayetmyo district, whilst there was a slight decrease in production in the Padaukpin field, that of the Yenanma field showed a considerable increase. An extension of the known producing area was proved in this field. During the year, the Burmah

Oil Company's deep test well at Monatkon was abandoned at 8,319 feet as no productive sand had been encountered.

The output from Kyaukpyu remained at its usual low level.

In Assam output of the Digboi field increased slightly. There has been no drilling in outside areas in the Assam Valley.

In the Surma Valley there was no production. A final test of the well at Masimpur showed that the horizons penetrated were of no value and the well was abandoned. The results of this well indicated that the structure underground was not as would be expected from the surface evidence, and resistivity observations were therefore carried out and a large number of core-holes were drilled on both flanks of the anticline in order to obtain geological evidence from the rocks hidden beneath the alluvium. The results of this work again showed that unexpected structural complications exist and at the end of the year seismic observations were about to start in a further attempt to ascertain the shape of the structure at depth. In addtion it is proposed to drill a deep core-hole in order to obtain evidence from considerable depth.

In the Punjab the Attock Oil Co., Ltd., operated the Khaur and Dhulian fields. In the Khaur field the deep test for the limestone was successfully cemented and is at present at 5,440 feet in limestone formation and is being tested. Results, however, are disappointing as the well is showing a considerable quantity of water with only a small quantity of oil and it does not promise to be an important producer. Shallow drilling has continued but has given only moderate results.

In the Dhulian field two deep wells were brought on to production in May and November 1937 respectively. These wells have been very steady producers. In the Board's bi-annual report dated 2nd February 1938 these wells were reported as producing 480 and 640 barrels of oil per day respectively. The production of the former fell to 454 barrels and the latter 480 barrels but the fall in the second well, to a very considerable extent, is due to a reduction in size of bean from 5/16" to under ¼", resulting in restriction of flow. This restriction is considered advisable partly from a storage point of view and partly in the interests of economical recovery of production.

Developments at other drilling wells are as follows:—

A well encountered a good show of black oil at 6,200 feet—probably worth 50 barrels per day,—but is being carried down

to the deep horizon of the two main producers. Another well which did not get black oil in any appreciable quantity has been drilled to 7,553 feet and is now being cemented. A further well has reached the depth of 3,020 feet. New sites have been selected for additional wells.

TABLE 32.—*Quantity and value of Petroleum produced in India and Burma during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Gls.	Rs.	£	Gls.	Rs.	£
India—						
Assam—						
Digboi . .	64,844,712	1,10,72,813	832,542	65,718,437	1,12,22,009	843,760
Punjab—						
Attock . .	4,396,792	10,99,198	82,646	9,939,420	24,84,855	186,831
TOTAL .	**69,241,504**	*1,21,72,011*	*915,188*	**75,657,857**	*1,37,06,864*	*1,030,591*
Burma—						
Kyaukpyu . .	13,402			12,437		
Minbu . . .	5,086,403			3,418,311		
Singu . . .	99,913,727			119,858,608		
Thayetmyo . .	712,455	4,96,99,506	3,736,805	2,001,180	5,95,06,155	4,474,147
Upper Chindwin .	2,815,672			2,502,140		
Yenangyat (including Lanywa).	27,147,566			25,067,655		
Yenangyaung .	131,300,895			121,804,034		
TOTAL .	**265,570,120**	*4,96,99,506*	*3,736,805*	**274,664,365**	*5,95,06,155*	*4,474,147*

TABLE 33.—*Imports of Kerosene Oil into India during the years 1936 and 1937.*

—	1936 (*a*).			1937 (*b*).		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
Union of Socialist Soviet Republics.	43,451,896	1,24,18,560	933,726	27,377,419	91,29,184	686,405
Roumania . .	256,000	98,980	7,442	308,000	1,06,473	8,006
Iran	6,180,381	12,94,081	97,299	8,218,665	30,27,007	227,595
Burma . . .	..	..	..	93,466,680	3,77,72,485	2,840,037
Sumatra . .	8,281,365	34,96,108	262,865	27,955,437	86,05,758	647,049
United States of America.	185,021	1,56,482	11,766	3,011,333	6,50,429	48,904
Other countries .	868,621	4,99,195	37,534	2,512,597	7,82,496	58,833
TOTAL .	**59,223,284**	*1,79,63,406*	*1,350,632*	**162,850,131**	*6,00,73,832*	*4,516,829*

(*a*) Figures relate to India and Burma.

(*b*) Figures include imports to Burma during January to March, 1937. The total quantity of kerosene oil imported into Burma during the whole of the year 1937 was 1,215,505 gallons consisting of 880,000 gallons from foreign countries, and 335,505 gallons from India including 8,204 gallons of foreign oil.

TABLE 34.—*Imports of Fuel Oils into India during the years 1936 and 1937.*

—	1936 (a).			1937 (b).		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Gals.	Rs.	£	Gals.	Rs.	£
From— Union of Socialist Soviet Republics.	3,456,847	4,84,449	36,425	..	..	..
Iran . . .	104,798,306	1,49,88,581	1,126,961	97,611,519	1,28,06,927	962,927
Borneo (British) .	10,549,735	20,61,764	155,020	13,050,640	26,67,862	200,593
Borneo (Netherlands).	12,318,009	19,98,113	150,234	5,426,441	9,81,040	73,762
Other countries .	5,731,554	8,52,688	64,112	11,720,456	19,92,089	149,781
TOTAL .	136,854,451	*2,03,85,595*	*1,532,752*	127,809,056	*1,84,47,938*	*1,387,063*

(a) Figures relate to India and Burma.
(b) Figures include imports to Burma during January to March, 1937. The total quantity imported into Burma during the whole of the year 1937 was 25,702,623 gallons.

TABLE 35.—*Exports of Paraffin Wax from India during the years 1936 and 1937.*

—	1936 (a).			1937 (b).		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
To— United Kingdom . .	17,367	73,83,913	555,181	9,400	42,00,674	315,840
Germany . . .	165	69,300	5,211	..	..	..
Netherlands . .	4,335	18,43,338	138,597	994	4,18,304	31,451
Belgium . . .	2,465	10,44,400	78,526	974	4,10,568	30,870
Italy	..	..	..	860	3,61,305	27,166
China	1,277	5,35,744	40,282	1,841	6,96,035	52,333
Union of South Africa .	2,753	11,54,201	86,782	1,903	7,29,616	54,858
Portuguese East Africa .	4,259	17,88,347	134,462	2,085	8,04,554	60,493
Canada . . .	2,044	8,57,080	64,442	835	3,50,700	26,368
United States of America	190	79,800	6,000	755	3,20,600	24,105
Mexico . . .	1,500	6,40,500	48,158	2,475	11,84,579	89,066
Columbia . . .	3,354	14,34,825	107,882	1,254	5,26,523	39,588
Chile	2,300	9,66,000	72,631	650	2,73,000	20,526
Australia . . .	740	3,12,060	23,463	127	53,340	4,011
Other countries . .	976	4,03,238	30,319	1,294	5,72,376	43,036
TOTAL .	43,725	*1,85,12,746*	*1,391,936*	25,447	*1,09,02,174*	*819,711*

(a) Figures relate to India and Burma.
(b) Figures include exports from Burma during January to March, 1937.

Salt.

There was a considerable increase in the production of salt in India in 1937, made up of large increases in the production in Bombay and Madras, with slight decreases in the production in Northern India and Sind.

The production in Aden was practically the same in 1937 as in 1936; the production in Burma showed a large increase.

The apparent decrease in the imports of salt in 1937 is due to the exclusion of the quantity of salt imported into Burma during the period April to December 1937, figures for which have not been received.

TABLE 36.—*Quantity and Value of Salt produced in India, Aden and Burma during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
India—						
Bengal	83	5,107	384	112	7,865	591
Bombay	400,682	18,19,647	136,816	489,742	22,86,482	171,916
Gwalior (*a*)	115	5,726	430	55	2,680	202
Madras	349,190	15,83,293	119,044	421,014	20,87,038	156,920
Northern India	468,118	32,97,030	247,897	465,712	31,74,484	238,683
Sind	130,034	6,58,722	49,528	116,386	5,88,816	44,272
TOTAL	**1,348,222**	*73,69,525*	*554,099*	**1,493,021**	*81,47,365*	*612,584*
Aden	355,394	20,71,011	155,715	355,166	(*b*)20,70,618	155,686
Burma	32,272	4,95,514	37,257	53,813	(*b*)8,24,953	62,026

(*a*) Figures relate to the official years, 1936-37 and 1937-38.
(*b*) Estimated.

TABLE 37.—*Quantity and value of Rock-Salt produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Salt Range	150,859	11,03,559	82,974	162,192	11,71,837	88,108
Kohat	18,226	56,322	4,235	20,855	64,187	4,826
Mandi	3,170	86,184	6,480	4,053	1,09,764	8,253
TOTAL .	**172,255**	*12,46,065*	*93,689*	**187,100**	*13,45,788*	*101,187*

TABLE 38.—*Imports of Salt into India during the years 1936 and 1937.*

—	1936 (*a*).			1937 (*b*).		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
From—	Tons.	Rs.	£	Tons.	Rs.	£
Germany	80,048	13,77,819	103,595	41,577	6,69,468	50,336
Aden and dependencies.	292,704	38,70,527	291,017	295,879	52,80,684	397,044
Egypt	12,375	2,08,380	15,668	1,000	15,269	1,148
Other countries . .	2,458	1,09,368	8,223	530	97,489	7,330
TOTAL .	**387,585**	*55,66,094*	*418,503*	**338,986**	*60,62,910*	*455,858*

(*a*) Figures relate to India and Burma.
(*b*) Figures include imports to Burma during January to March, 1937.

Saltpetre.

Although complete statistics of production of saltpetre in India are no longer available (*see Rec. Geol. Surv. Ind.*, LXIV, p. 289), yet the export figures may be accepted as a fairly reliable index to the general state of the industry, for, excepting a few hundreds of tons required for internal consumption as fertiliser, most of the output is exported to foreign countries. The quantity exported increased from 162,808 cwts. valued at Rs. 11,47,437 (£86,273) in 1936, to 167, 147 cwts. valued at Rs. 11,17,844 (£84,048) in 1937.

Nevertheless, figures of production of refined saltpetre—without values—are available for tracts worked under the supervision of the Northern India Salt Revenue Department. The production figures for the financial years 1936-37 and 1937-38 are :—

	1936-37.	1937-38.
	Tons.	Tons.
Bihar	1,004	963
Punjab	8,566	5,788
United Provinces . . .	1,648	1,881
TOTAL .	11,218	8,632

A certain amount of nitrate of potash is used for agricultural purposes on the tea gardens of India. During the War, when it was impossible to obtain supplies of imported potash, the amount of locally produced nitrate utilised in this way reached an appreciable figure. The practice continued and the quantity estimated to have been absorbed for fertilising purposes on tea gardens in 1937 was 500 tons against 600 tons in 1936.

TABLE 39.—*Distribution of Saltpetre exported from India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom .	49,934	3,62,686	27,270	37,251	2,80,861	21,117
Ceylon	19,336	1,10,854	8,335	21,886	1,22,405	9,208
Mauritius and dependencies.	74,264	5,12,335	38,521	77,983	4,83,891	36,388
Other countries . .	19,274	1,61,560	12,147	30,027	2,30,687	17,345
TOTAL .	162,808	*11,47,437*	*86,273*	167,147	*11,17,844*	*84,048*

Silver.

The production of silver from the Bawdwin mines of the Burma Corporation, Limited, during 1937 rose by 228,000 ozs. as compared with 1936, accompanied by a rise in value of Rs. 4,89,414 (£36,706) (*see* Table 3 and Lead, p. 338).

The output of silver obtained as a bye-product from the Kolar gold mines of Mysore showed a fall of 703 ozs.

The amount of silver bullion and coin exported during the year was 5,311,827 ozs. valued at Rs. 1,09,93,186 (£826,555) as compared with 2,763,274 ozs. valued at Rs. 34,30,310 (£257,918), during 1936.

TABLE 40.—*Quantity and value of Silver produced in India and Burma during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Ozs.	Rs.	£	Ozs.	Rs.	£
India—						
Mysore State . .	25,345	33,619	2,528	24,642	32,343	2,432
Burma—						
Northern Shan States .	5,952,000	68,71,584	516,660	6,180,000	73,60,998	553,458

Tin.

A further increase is recorded in the production of tin concentrates from Burma, including Karenni State, from 6,494·8 tons valued at Rs. 1,03,83,166 (£780,689) in 1936, to 6,622·5 tons valued at Rs. 1,09,59,215 (£824,001) in 1937. This is the highest quantity yet recorded in any one year. Tavoy and Karenni State (Mawchi) show increases, and Mergui a decrease. There was no reported output of block tin.

Imports of unwrought tin rose from 46,084 cwts. valued at Rs. 62,72,482 (£471,615) in 1936 to 51,489 cwts. valued at Rs. 79,65,610 (£598,918) in 1937; 90·7 per cent. of these imports came from the Straits Settlements.

TABLE 41.—*Quantity and value of Tin concentrates produced in Burma during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Burma—						
Amherst	55·0	65,879	4,953	36·4	67,233	5,055
Mergui	1,896·7	28,79,881	216,532	1,694·5	29,49,155	221,741
Tavoy	2,718·0	45,15,193	339,488	2,919·8	47,53,262	357,388
Thaton	2·6	4,125	310	4·9	6,720	505
Yamethin	17·5	29,332	2,206	55·1	97,200	7,308
Mong Pai State . .	1·5	2,901	218	—	—	—
Karenni State	1,801·7	(*a*)28,85,855	216,982	1,911·8	(*a*)30,85,645	232,004
TOTAL .	**6,494·8**	*1,03,83,166*	*780,689*	**6,622·5**	*1,09,59,215*	*824,001*

(*a*) Estimated.

TABLE 42.—*Imports of Unwrought Tin (blocks, ingots, bars and slabs) into India during the years 1936 and 1937.*

—	1936 (*a*).			1937 (*b*).		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
From—						
United Kingdom . .	988	1,45,312	10,926	1,057	1,75,919	13,227
Straits Settlements .	44,625	60,61,809	455,775	46,708	74,28,957	558,568
Other countries . .	471	65,361	4,914	3,724	3,60,734	27,123
TOTAL .	**46,084**	*62,72,482*	*471,615*	**51,489**	*79,65,610*	*598,918*

(*a*) Figures relate to India and Burma.
(*b*) Figures include imports to Burma during January to March, 1937. Total quantity of tin blocks imported into Burma during the whole of the year 1937 was 879 cwts. consisting of 850 cwts. from foreign countries and 29 cwts. of foreign merchandise from India.

Tungsten.

An important increase both in quantity and especially in value of the output of wolfram from Burma has to be recorded, namely from 4,552 tons valued at Rs. 40,91,396 (£307,624) in 1936 to 4,997·7 tons valued at Rs. 80,22,748 (£603,214) in 1937. The price per unit rose during 1937 from 33·5 shillings to 76·58 shillings, the average being 69·83 shillings. This beats the peak

production of 4,542 tons in 1917, under War stimulus, by 455·7 tons. The rise in output during 1937 was shared by all producing districts.

TABLE 43.—*Quantity and value of Tungsten concentrates produced in India and Burma during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
India—	Tons.	Rs.	£	Tons.	Rs.	£
Jodhpur State	..	..	..	13·0	24,500	1,842
Burma— Amherst	..	..	..	0·5	480	36
Mergui	241·8	1,47,062	11,057	276·9	3,31,200	24,902
Tavoy	2,721·6	24,93,691	187,496	2,760·2	45,08,034	338,950
Thaton	25·3	20,240	1,522	58·7	92,736	6,973
Yamethin	145·5	1,48,964	11,200	252·0	4,71,759	35,471
Mong Pai State	6·0	6,255	470	..	..	..
Karenni State	1,421·8	(*a*)12,75,184	95,879	1,649·4	(*a*)26,18,539	196,882
TOTAL	**4,562·0**	*40,91,396*	*307,624*	**4,997·7**	*80,22,748*	*603,214*

(*a*) Estimated.

Zinc.

The production of zinc concentrates by the Burma Corporation Limited, in the Northern Shan States, fell from 76,807 tons valued at Rs. 40,34,641 (£303,356) in 1936 to 73,552 tons valued at Rs. 54,40,421 (£409,054) in 1937, with improved price. The exports during the year under review amounted to 82,686 tons, valued at Rs. 54,95,366 (£413,185) against 88,845 tons, valued at Rs. 39,08,049 (£293,838) in the preceding year.

Zircon.

The output of zircon, a mineral obtained as a concurrent product in the collection of ilmenite and monazite in Travancore State, decreased from 2,209·9 tons valued at Rs. 84,258 (£6,335) in 1936 to 1,329 tons valued at Rs. 39,036 (£2,935) in 1937. The exports were 1,037 tons in 1937 against 1,990 tons in 1936 and 1,470 tons in 1935.

III.—MINERALS OF GROUP II.

Amber. The production of amber in the Myitkyina district, Burma, was 3·7 cwts. valued at Rs. 152 (£12) in 1934, 18·6 cwts. valued at Rs. 2,100 (£158) in 1935, 32·4 cwts. valued at Rs. 5,440 (£409) in 1936, and 38·7 cwts. valued at Rs. 8,880 (£668) in 1937.

Apatite. The production of apatite in the Singhbhum district, Bihar, was 22 tons valued at Rs. 3,300 (£244) in 1930, but *nil* in 1931 to 1937. The output of apatite in the Trichinopoly district, Madras, rose from 37 tons valued at Rs. 372 (£28) in 1933 to 59 tons valued at Rs. 885 (£67) in 1934, to 102 tons valued at Rs. 1,532 (£115) in 1935, to 128 tons valued at Rs. 1,315 (£99) in 1936, and to 166 tons valued at Rs. 1,660 (£125) in 1937.

Aquamarine. The output of aquamarine from the deposits of Daso in Ladakh in Kashmir rose from 686 tolas (39,000 carats) valued at Rs. 686 (£52) in 1933 to 1,221 tolas (69,471 carats) in 1934. The value of the 1934 production was not reported and there was no production during 1935 and 1936. In 1937 the output was 110 tolas.

Asbestos. The total production of asbestos in India during 1934 was 25·4 tons valued at Rs. 4,140 (£311), made up of 20 tons valued at Rs. 2,500 (£188) from Singhbhum, Bihar, and 5·4 tons valued at Rs. 1,640 (£123) from the Cuddapah district, Madras. In 1935 the production amounted to 62·7 tons, composed of 2·7 tons valued at Rs. 1,267 (£95) from the Cuddapah district, and 60 tons valued at Rs. 3,300 (£248) from Seraikela State in the Eastern States Agency. In 1936 the production was 56·5 tons valued at Rs. 3,107 (£234) from Seraikela State, and in 1937, 100 tons valued at Rs. 6,000 (£451) from Seraikela State and 9 cwts. valued at Rs. 22 (£2) from Ajmer-Merwara.

Barytes. The production of barytes in India rose from 3,813 tons valued at Rs. 35,263 (£2,651) in 1934 to 5,493 tons valued at Rs. 34,954 (£2,628) in 1935, but fell slightly to 5,114 tons valued at Rs. 16,049 (£1,206) in 1936. In 1937 the production more than tripled, to 15,689 tons valued at Rs. 1,49,260 (£11,223). The chief producing district was Cuddapah in the Madras Presidency.

TABLE 44.—*Quantity and value of Barytes produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Madras—						
Cuddapah	4,600	11,762	884	15,405	1,46,720	11,032
Kurnool	314	2,324	175	130	1,150	86
Rajputana—						
Alwar State . . .	151	1,363	102	154	1,390	105
Jaipur State . . .	40	600	45	..	..	..
TOTAL .	5,114	*16,049*	*1,206*	15,689	*1,49,260*	*11,223*

Bauxite. In 1930, 2,514 tons of bauxite were produced, of which 719 tons came from the Kaira district of Bombay, and 1,795 tons from the Jubbulpore district of the Central Provinces. In 1931 the output from the Jubbulpore district was 4,298 tons, in 1932 4,467 tons, and in 1933 1,000 tons valued at Rs. 3,000 (£226). In 1934 the output was reduced to only 18 tons valued at Rs. 90 (£7), from the Jubbulpore district, but rose in 1935 to 7,635 tons valued at Rs. 15,270 (£1,148) falling again to 3,644 tons valued at Rs. 7,288 (£548) in 1936. In 1937 there was a large increase, to 9,558 tons valued at Rs. 16,319 (£1,227), from Jubbulpore district, and Kaira district again recorded production, 5,592 tons, valued at Rs. 45,520 (£3,423).

Bentonite. In Jodhpur State, Rajputana, there was in 1937 a production of 90 tons of bentonite valued at Rs. 900 (£68), and in Mirpur district, Kashmir, 56 tons, valued at Rs. 1,350 (£102), in 1936, not recorded in time for last year's Review.

Beryl. In 1932 there was a production in Ajmer-Merwara of 281 tons of beryl valued at Rs. 5,281 (£397) which rose to 324 tons valued at Rs. 7,261 (£546) in 1933, falling to 55 tons valued at Rs. 1,650 (£124) in 1934, rising in 1935 to 139 tons valued at Rs. 8,519 (£641), but falling again to 98 tons valued at Rs. 6,184 (£465) in 1936 and to 26·6 tons valued

TABLE 45.—*Production of Building materials and Road*

	GRANITE.		LATERITE.		LIME.		LIMESTONE AND KANKAR.	
—	Quantity.	Value.	Quantity.	Value	Quantity.	Value.	Quantity.	Value.
	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.
Assam	12,787	35,172	15,618	16,669	..	..	67,390	99,734
Baroda	..	..	..	..	..	..	..	..
Bengal	88,412	99,074	..	..	..	..	..	..
Bihar	488,792	4,84,084	..	..	..	..	345,037	4,67,757
Bombay	..	..	4,805	6,092	..	..	120	1,800
Central India . .	..	..	..	..	27,924	1,71,724	141,766	48,058
Central Provinces .	15,753	12,052	65	17	..	..	607,608	6,86,489
Eastern States Agency.	1,999	440	141	31	..	..	(a)749,866	17,30,693
Gwalior	..	..	..	..	..	..	89,295	38,513
Kashmir	..	..	..	..	..	..	..	..
Madras	129,460	1,34,952	..	..	..	..	141,943	76,200
Mysore	3,015	23,366	737	1,121	3,329	60,348	9,146	52,440
North-West Frontier Province.	..	..	..	..	..	..	..	..
Orissa . . .	..	..	68	19	..	..	3	..
Punjab	69,523	46,675	..	..	..	..	294,082	2,23,507
Rajputana	..	..	..	..	..	..	369,949	6,34,473
Sind	30,127	18,051	..	..	..	..	..	..
United Provinces .	73,087	91,227	..	..	..	..	731,347	5,38575
TOTAL .	**9,12,955**	*9,45,093*	**21,434**	*23,949*	**31,253**	*2,32,072*	**3,547,561**	*45,98,239*
Burma	..	..	..	..	..	..	..	..

(a) Includes 34,408 tons
(b) Includes 1,449 tons
(c) Includes production of
Separate figures of production

metal in India and Burma during the year 1937.

MARBLE.		SANDSTONE		SLATE.		TRAP.		MISCELLANEOUS BUILDING MATERIAL AND ROAD-METAL.		TOTAL VALUE (£1=Rs 13·3).	
Quantity.	Value.	Quantity.	Value	Quantity.	Value.	Quantity.	Value	Quantity.	Value		
Tons	Rs.	Tons	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Rs.	£
..	..	13,605	21,218	..	..	..	..	233,111	4,62,195	6,34,988	47,743
19	120	..	..	..	..	..	..	..	..	120	9
..	..	..	..	..	..	..	..	..	..	99,074	7,440
..	..	40,772	43,787	573	8,718	2,114	965	101,855	33,610	10,38,921	78,114
..	..	..	..	..	..	311,417	4.45,302	67,667	60,721	5,13,915	38,640
..	..	..	..	..	..	..	..	6,336	16,060	2,85,842	17,732
..	..	..	..	..	..	..	..	30,331	38,094	7,31,652	55,011
..	..	..	..	..	..	..	..	..	..	17,31 164	130,163
..	..	..	..	..	..	..	..	..	..	38,513	2,896
..	..	..	..	..	..	..	..	13,223	8,468	8,468	637
..	..	..	..	..	..	..	..	753,989	4,39,073	6,50,225	48,880
..	..	..	..	4	37	..	..	405,705	6,84,994	8,22,306	61,828
..	..	..	..	..	..	..	..	1,604	3,625	3,625	273
..	..	34	17	..	..	..	..	2,734	490	526	40
..	..	..	..	7,180	1,39,190	..	..	986	1,528	4,10,900	30,895
8,097	40,469	(b) 226,935	6,57,572	58	870	..	..	193,901	1,44,676	14,78,060	111,132
..	..	..	..	..	..	..	..	..	..	18,051	1,357
..	..	6,296	10,043	1,426	5,456	..	..	267,274	6,28,229	12,73,530	95,754
8,116	***40,589***	**287,642**	*7,32,637*	**9,241**	*1,54,271*	**313,531**	***4,46,267***	**2,108,716**	***25,16,763***	***96,89,880***	***728,562***
..	..	..	..	..	..	..	..	(c) 3,126,587	25,87,512	25,87,512	194,550

of dolomite.
of sand used for glass manufacture.
granite laterite, limestone, etc.
are not available.

at Rs. 1,969 (£148). This beryl is shipped to Germany and the United States of America for use as beryllium-ore, *i.e.*, for the extraction of the metal. The Indian beryl is of high grade and fetches from £7 to £10 per ton *c.i.f.* in America and Europe, so that it is obviously undervalued in the returns. There appears to be no previous example of the production anywhere in the world of beryl on such a large scale.

Bismuth.

The production of native bismuth from the Tavoy district, Burma, was in 1935, 224 lbs. valued at Rs. 211 (£16) and in 1936, 112 lbs. valued at Rs. 112 (£8). In 1937, 246 lbs. were produced.

Building materials and road-metal.

The total estimated value of building materials and road-metal produced in India and Burma in the year under consideration was Rs. 1,22,77,392 (£923,112) against Rs. 1,08,62,263 (£816,712) in 1936. Certain returns supplied in cubic feet have been converted into tons on the basis of certain assumed relations between volume and weight.

The production of limestone and *kankar* during the year amounted to nearly 3½ million tons, and if weight of material won were the criterion, then limestone would be rated next to coal in order of importance. The increased output of limestone of recent years is partly due to its use as a flux in the iron and steel industry and in the manufacture of cement.

Clays.

There was a rise in the output of clays from *318,512 tons valued at Rs. 2,93,373 (£22,057) in 1936, to 346,989 tons, valued at Rs. 3,40,420 (£25,596) in 1937. Practically the whole of the large production of Madras is from Travancore State for the manufacture of tiles and bricks.

Corundum.

The production of corundum in the Salem district, Madras, amounted to 28 tons valued at Rs. 6,181 (£465) in 1935 and in 1936 the output was 1½ tons valued at Rs. 420 (£32). No production was recorded in 1937. There was, however, an ouput of 56,560 tolas (13 cwts.) of corundum and of 13,718 tolas (3 cwts.) of sapphire with corundum in 1934 and 1935, respectively, from Soomjam in the Padar district of Kashmir. In 1936 there was an output of 49,155 tolas, the figure being received too late for inclusion in last year's Review, and in 1937, 1,869 tolas; (*See* also Sapphire, p. 367).

* Revised.

TABLE 46.—*Production of Clays in India and Burma during 1937.*

—	1937.		
	Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£
India—			
Assam	18,383	6,894	518
Baroda	500	15,000	1,128
Bengal	25,669	36,988	2,781
Bihar	11,687	1,35,547	10,192
Central India	1,505	2,072	155
Central Provinces	47,967	27,999	2,105
Delhi	3,538	7,047	530
Kashmir	3	9	1
Madras (including Madras States) .	104,547	21,066	1,584
Mysore	21,922	29,975	2,254
Orissa	10,193	24,309	1,828
Punjab	81,105	13,439	1,010
Rajputana	720	1,501	113
United Provinces	1,158	399	30
TOTAL .	**328,140**	*3,21,295*	*21,158*
Burma	18,092	18,175	1,367

Felspar.

The output of felspar in 1934 was 628 tons valued at Rs. 6,311 (£474), which rose in quantity to 702 tons in 1935, with a fall in value, however, to Rs. 4,943 (£372), rising again to 784·5 tons valued at Rs. 6,037 (£454), in 1936 and falling to 487 tons, valued at Rs. 3,390 (£255) in 1937. This total is made up of 143 tons from Mysore, valued at Rs. 858, 76 tons from Alwar State, Rajputana, valued at Rs. 665 and 268 tons from Ajmer-Merwara, valued at Rs. 1,867.

Fuller's earth.

There was a rise in the reported production of fuller's earth from 6,649 tons valued at Rs. 71,672 (£5,389) in 1936 to 7,416 tons valued at Rs. 75,017 (£5,640) in 1937. The increase was mainly from Khairpur State.

TABLE 47.—*Quantity and value of Fuller's earth produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Sind—						
Hyderabad	879	14,950	1,124	..	..	..
Punjab States Agency—						
Khairpur State	2,928	(*a*) 29,280	2,201	4,844	(*a*) 48,440	3,642
Central Provinces—						
Jubbulpore	..	..	..	45	67	5
Rajputana—						
Bikaner State	1,574	12,264	922	869	8,315	625
Jaisalmer State	17	188	14	18	195	15
Jodhpur State	1,251	15,000	1,128	1,640	18,000	1,353
TOTAL	**6,649**	*71,672*	*5,389*	**7,416**	*75,017*	*5,640*

(*a*) Estimated.

Garnet sand.

In 1937 there was an output of about 330 tons of garnet sand valued at Rs. 1,650 (£124) from Tinnevelly district, Madras.

Graphite.

In 1935 there was an output of 557 tons of graphite valued at Rs. 11,481 (£863), composed of 406 tons valued at Rs. 9,274 from Betul district, C. P., 150 tons valued at Rs. 2,157 from Kolar district, Mysore, and 1 ton valued at Rs. 50 from Vizagapatam district, Madras. In 1936 this fell to 388 tons valued at Rs. 4,400 (£331), 237 tons valued at Rs. 1,380 being from Betul district and 151 tons valued at Rs. 3,020 from Kolar district. In 1937 there was no production from Betul district, but 228 tons, valued at Rs. 8,892 (£669) from Patna State, Eastern States Agency, 10 tons valued at Rs. 1,000 (£75) from Vizagapatam, and the Kolar output more than doubled, to 320 tons, valued at Rs. 6,410 (£482), the total being 558 tons.

Gypsum.

There was a fall of 8,314 tons in the output of gypsum, from 54,404 tons valued at Rs. 98,366 (£7,396) in 1936, to 46,090 tons valued at Rs. 1,18,543 (£8,913) in 1937 with a rise in value.

TABLE 48.—*Quantity and value of Gypsum produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Kashmir State	..	..	..	7	44	3
Madras—						
Trichinopoly	1,505	14,171	1,066	1,597	15,603	1,173
Punjab—						
Jhelum	19,304	22,052	1,658	25,846	36,859	2,771
Rajputana—						
Bikaner State	15,975	28,079	2,111	7,108	40,265	3,028
Jaisalmer State	264	1,008	76	265	1,010	76
Jodhpur State	17,300	33,000	2,481	11,000	24,000	1,805
United Provinces—						
Garhwal	56	56	4	267	762	57
TOTAL	**54,404**	*98,366*	*7,396*	**46,090**	*1,18,543*	*8,913*

Miscellaneous refractory materials.

The output of kyanite and quartzite and similar rocks in Singhbhum district, Bihar, and Kharsawan State of the Eastern States Agency, is partly for purposes of export, and partly for use in India, such as for furnace linings at Jamshedpur. The data for 1936 and 1937 are assembled in Table 49, from which it will be seen that there has been an increase in total output from 41,436 tons valued at Rs. 3,96,316 (£29,708) in 1936 to 47,542 tons, valued at Rs.7,44,398 (£55,970) in 1937. The most valuable of these materials is kyanite extracted for export by the Indian Copper Corporation from Lopso Hill in Kharsawan. The quartz-mica-schist all came from Singhbhum district. Of the total production of 15,197 tons of quartzite, 14,362 tons came from Singhbhum district, and only 825 tons from Seraikela State.

TABLE 49.—*Quantity and value of Miscellaneous Refractory Materials produced in Bihar and Eastern States Agency during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Kyanite	24,787	3,53,178	26,555	29,321	6,84,867	51,494
Quartz-mica-schist . . .	1,462	(*a*) 14,474	1,088	3,025	31,400	2,361
Quartzite	15,049	26,829	2,017	15,197	28,131	2,115
TOTAL .	**41,298**	*3,94,481*	*29,660*	**47,543**	*7,44,398*	*55,870*

(*a*) Estimated.

There was a decrease in the reported production of ochre from 6,298 tons valued at Rs. 36,557 (£2,749) to 5,977 tons valued at Rs. 23,784 (£1,788) in 1937. Central India was mainly responsible for this decrease, Panna State producing only 119 tons in 1937, against 1,571 tons in 1936, and sohawal State produced 1,912 tons in 1937, against 593 tons in 1936.

Ochre.

TABLE 50.—*Quantity and value of Ochre produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar	510	(*a*) 2,550	192	..	..	..
Central India	2,357	17,617	1,325	2,270	10,631	799
Central Provinces . . .	1,894	4,738	356	2,455	7,195	541
Eastern States Agency . .	1	9	1	..	..	..
Gwalior	357	2,176	164	..	..	..
Madras (including Madras States)	1,021	7,676	577	724	3,795	285
Orissa	..	..	..	125	946	71
Rajputana	12	221	16	403	1,217	92
United Provinces . . .	146	1,570	118	..	..	..
TOTAL .	**6,298**	*36,557*	*2,749*	**5,977**	*23,784*	*1,788*

(*a*) Estimated.

Ruby, Sapphire and Spinel.

After the liquidation of the Burma Ruby Mines, Limited, and the final cessation of the operations of this company in 1931, there was an interval during which reliable statistics of production of gem-stones in the Mogok Stone Tract were unobtainable. Work, however, is still continued by local miners; in addition a certain amount of work is being done under extraordinary licenses. For 1932 no returns were available, except that a fine ruby of 17 carats, a fine sapphire of about 90 carats and a good star sapphire of 453 carats were mined. For 1933 the only return was of 1,103 carats of rubies. For 1934, however, there was a reported production of 21,622 carats of rubies valued at Rs. 36,011 (£2,708) and 153 carats of sapphires valued at Rs. 330 (£25); for 1935, 98,753 carats of rubies valued at Rs. 1,10,213 (£8,287), 202 carats of sapphires valued at Rs. 329 (£25) and 6,687 carats of spinels valued at Rs. 3,850 (£289). For 1936 the return was 155,381 carats of rubies valued at Rs. 97,103 (£7,301), and 172 carats of sapphires valued at Rs. 242 (£18), and in 1937, 157,308 carats of rubies, valued at Rs. 90,990 (£6,841) and 4,392 carats of sapphires, valued at Rs. 3,035 (£228).

In addition, the production was reported from Soomjam in the Padar district of Kashmir State in 1936, of 491,747 carats of sapphire, valued at Rs. 22,376 (£1,682), and, in 1937, of 18,344 carats of sapphire, valued at Rs. 550 (£41) (*see* also Corundum, p. 362). The sapphire deposits of Kashmir have long been known, but on account of their high altitude they are worked only occasionally.

TABLE 51.—*Quantity and value of Ruby and Sapphire produced in India and Burma during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Carats.	Rs.	£	Carats.	Rs.	£
India—						
Kashmir State .	491,747 (Sapphire).	22,376	1,682	18,344 (Sapphire).	550	41
Burma—						
Katha . . .	155,381 (Rubies).	97,103	7,301	157,308 (Rubies).	90,990	6,841
	172 (Sapphire).	242	18	4,392 (Sapphire).	3,035	228
TOTAL .	155,553	*97,345*	*7,319*	161.700	*94,025*	*7,069*

The output of soda (*phulli*) in Kashmir State was 7 tons valued at Rs. 194 (£15) in 1934; the production in 1935 and 1937, was *nil*, and 1 ton, valued at Rs. 33 (£2) in 1936, a figure which was received too late for inclusion in last year's Review.

Soda.

There was an increase in the production of steatite from 9,968 tons valued at Rs. 1,56,983 (£11,803) in 1936 to 13,040 tons, valued at Rs. 1,55,221 (£11,671) in 1937, a slight fall in value. The increased production came principally from Jaipur State, Jubbulpore remaining stationary, and Hazaribagh falling, these being the principal sources.

Steatite.

TABLE 52.—*Quantity and value of Steatite produced in India during the years 1936 and 1937.*

—	1936.			1937.		
	Quantity.	Value (£1 = Rs. 13·3).		Quantity.	Value (£1 = Rs. 13·3).	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar—						
Hazaribagh	1,574	9,804	737	918	5,678	427
Singhbhum	125	437	33	82	287	22
Central India—						
Bijawar State	90	1,987	149	55	1,220	92
Central Provinces—						
Bhandara	50	125	9	253	190	14
Jubbulpore	1,857	14,369	1,080	1,858	9,390	706
Eastern States Agency—						
Mayurbhanj State	29	2,800	211	68	6,552	493
Seraikela State	64	4,172	314	153	5,239	394
Madras—						
Anantapur	40	600	45	13	195	15
Nellore	74	2,612	196	27	1,080	81
Salem	260	5,235	394	263	3,365	253
Mysore State	86	591	44	90	601	45
Rajputana—						
Alwar State	..	..	..	106	724	54
Jaipur State	5,570	1,18,420	8,528	9,041	1,20,000	9,023
United Provinces—						
Hamirpur	135	556	42	106	550	41
Jhansi	14	275	21	7	150	11
TOTAL	**9,968**	***1,56,983***	***11,803***	**13,040**	***1,55,221***	***11,671***

Until recently, figures of production of ammonium sulphate as a bye-product at the coking plants of iron and steel works and collieries have been collected only every five years for the Quinquennial Reviews of Mineral Production. They prove, however, to be of such general interest that it has been thought desirable to report them annually, and the figures for 1936 and 1937 are shown in Table 53. Values have not been obtained, and ammonium sulphate does not therefore find a place in Table 1. The figures show an unimportant increase in production from 17,603 tons in 1936 to 18,150 tons in 1937. The exports for these two years were 3,232 and 1,919 tons respectively.

Sulphate of ammonia.

TABLE 53.—*Production of Sulphate of Ammonia in India during the years 1936 and 1937.*

——	1936.	1937.
	Tons.	Tons.
The Tata Iron and Steel Company, Limited . .	5,778	6,474
The Indian Iron and Steel Company, Limited . .	9,006	8,673
The Burrakur Coal Company, Limited . . .	1,178	1,135
State Railways, Coal Department, Giridih. . .	308	532
The Bararee Coke Company, Limited . . .	1,333	1,336
TOTAL .	**17,603**	**18,150**

11·2 cwts. of tantalite valued at Rs. 301 (£23) were produced in the Monghyr district of Bihar and Orissa during 1937.

Tantalite.

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 54.—*Statement of Mineral Concessions granted during the year 1937.*

AJMER-MERWARA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Ajmer . .	(1) Messrs. Ghisoolal Sethi & Sons.	Mica and beryl .	P. L. (Renewal).	3·04	11th December 1937.	1 year.
Do. . .	(2) Mr. Nand Kishore Pahladka.	Do. . .	P. L. .	1	23rd December 1937.	Do.
Do. . .	(3) L. Kanhiyalal .	Mica, beryl and felspar.	P. L. .	0·74	Do. .	Do.
Do. . .	(4) Mr. Nand Kishore Pahladka.	Mica and beryl .	P. L. .	1·16	Do. .	Do.
Do. . .	(5) Mr. Abdul Ghani .	Mica, felspar and beryl.	P. L. .	0·12	22nd December 1937.	Do.
Do. . .	(6) L. Pragnarain .	Mica, felspar and china clay.	M. L. .	0·8	14th March 1937.	5 years.
Do. . .	(7) Do. . .	Mica and beryl ore .	P. L. (Renewal).	1·6	17th August 1937.	Do.
Do. . .	(8) L. Goverdhanlal Rathi.	Graphite . .	P. L. .	0·12	11th August 1937.	Do.
Do. . .	(9) L. Pragnarain .	Mica, felspar and quartz.	P. L. (Renewal).	1·82	9th September 1937.	3 months.
Do. . .	(10) L. Goverdhanlal Rathi.	Mica and beryl .	P. L. .	1·8	1st September 1937.	1 year.
Do. . .	(11) L. Ladoolal Kataria.	Mica . . .	P. L. (Renewal).	1·36	2nd October 1937.	Do.
Do. . .	(12) Do. . .	Do. . . .	P. L. (Renewal).	0·4	Do. .	Do.
Do. . .	(13) L. Kanhiyalal .	Mica, beryl and felspar.	P. L. .	0·34	20th November 1937.	Do.
Do. . .	(14) Do. . .	Mica and beryl .	P. L. .	0·70	Do. .	Do.
Do. . .	(15) Messrs. Ghisoolal Sethi & Sons.	Do. . .	P. L. (Renewal).	2·78	11th December 1937.	Do.
Do. .	(16) L. Pragnarain .	Muscovite . .	P. L. (Renewal).	1·98	20th October 1937.	Do.
Do. . .	(17) Do. . .	Mica and felspar .	P. L. .	3·2	20th September 1937.	Do.
Do. . .	(18) L. Goverdhanlal Rathi.	Asbestos . .	P. L. .	0·54	4th November 1937.	Do.
Do. . .	(19) Mr. Abdul Ghani .	Mica . . .	P. L. (Renewal).	3·22	11th November 1937.	Up to 13th March 1938.
Do. . .	(20) Mr. Onkermal .	Mica and beryl .	P. L. .	0·8	13th November 1937.	1 year.
Do. . .	(21) Lala Goverdhanlal Rathi.	Do. . .	P. L. .	0·6	Do. .	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

AJMER-MERWARA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Ajmer . .	(22) Messrs. Abdul Ghani & Co.	Mica, felspar and beryl-ore.	P. L. . (Renewal).	3·54	16th February 1937.	1 year.
Do. . .	(23) Lala Ladoolal Kataria.	Mica and beryl .	P. L. .	0·88	15th February 1937.	Do.
Do. . .	(24) L. Prag Narain .	Asbestos and kyanite	P. L. .	1·26	28th February 1937.	Do.
Do. . .	(25) Messrs. Abdul Ghani.	Mica, beryl-ore and felspar.	P. L. .	4·28	13th March 1937.	Do.
Do. . .	(26) Do. . .	Do. . .	P. L. .	2·44	20th March 1937.	Do.
Do. . .	(27) Messrs. Ghisalal Sethi & Sons.	Mica and beryl .	P. L. .	2·78	19th November 1936.	Do.
Do. . .	(28) Messrs. Abdul Ghani & Co.	Mica, beryl-ore and felspar.	P. L. .	6·46	6th April 1937	Do.
Do. . .	(29) L. Goverdhanlal Rathi of Nasirabad.	Do. . .	P. L. . (Renewal).	0·56	13th April 1937.	Do.
Do. . .	(30) Messrs. Beharilal Shyam Sunderlal.	Mica and beryl .	P. L. .	4·26	27th April 1937.	Do.
Do. . .	(31) L. Goverdhanlal Rathi.	Mica . . .	P. L. .	4·34	21st May 1937	Do.
Do. . .	(32) Mr. J. K. Soneji .	Do. . . .	P. L. . (Renewal).	0·68	7th July 1937	Do.
Do. . .	(33) Messrs. Abdul Ghani & Co.	Do. . . .	P. L. .	1·6	5th July 1937	Do.
Beawar .	(34) Mr. D. P. Modi .	Do. . . .	P. L. .	1·6	18th October 1937.	Do.
Do. . .	(35) Mr. D. P. Mody .	Do. . . .	P. L. .	7·16	Do. .	Do.
Do. . .	(36) Lala Goverdhanlal Rathi.	Do. . . .	P. L. .	0·08	27th January 1937.	Do.
Do. . .	(37) L. Goverdhanlal Rathi.	Do. . . .	P. L. .	7·5	24th November 1937.	Do.
Do. . .	(38) L. Kanhiyalal .	Mica, felspar and beryl.	P. L. .	2·1	13th August 1937.	Do.
Do. . .	(39) Lala Goverdhanlal Rathi.	Asbestos and soap stone.	P. L. .	0·6	Do. .	Do.
Do. . .	(40) L. Kanhiyalal .	Mica, beryl and felspar.	P. L. .	1·4	6th June 1937	Do.
Do. . .	(41) Qazi Syed Mohd. Niaz Ali.	Do. . .	P. L. .	1·84	24th August 1937.	Do.
Do. . .	(42) Do. . .	Asbestos . .	P. L. .	0·72	20th April 1937.	Do.
Do. . .	(43) Do. . .	Mica . . .	P. L. . (Renewal).	14·12	3rd April 1937	Do.
Deolia Khurd Estate.	(44) Mr. J. K. Soneji .	Do. . . .	M. L. .	14·12	Do. .	3 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

AJMER-MERWARA—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagola Estate	(45) Messrs. Labhchand & Co.	Mica	M. L. .	14·12	22nd December 1937.	10 years.
Nimod Estate.	(46) Mr. Nusserwanji .	Beryl-ore . . .	M. L. .	Whole estate.	25th October 1937.	Do.

ASSAM.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nongstoin State.	(47) Mr. H. M. Hance	Sillimanite, corundum and all associated refractory minerals.	P. L.	640	24th April 1937.	1 year.

BALUCHISTAN.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kalat . .	(48) Rai Sahib Tikamdas Girdharidas.	Coal	M. L. .	80	4th January 1937.	30 years
Do. . .	(49) Mullick Wilayet Hussain.	Do.	M. L. .	80	28th August 1937.	Do.
Do. . .	(50) Do. . .	Do.	M. L. .	80	28th September 1937.	Do.
Do. . .	(51) Do. . .	Do.	M. L. .	80	2nd September 1937.	Do.

BIHAR.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh .	(52) Babu Mathura Prasad Rajgarhia.	Mica	M. L. .	108	1st March 1936.	30 years with an option of renewal for the like period.
Do. .	(53) Rai Bahadur S. K. Sahana.	Do.	M. L. .	40	1st November 1936.	Do.
Do. .	(54) Do. . .	Do.	M. L. .	46	Do. .	Do.
Do. .	(55) Do. . .	Do.	M. L. .	40	1st January 1937.	Do.
Do. .	(56) Khan Bahadur M. A. Momin.	Do.	M. L. .	57	Do. .	Do.
Do. .	(57) Babu Gangadhar Samanta.	Do.	M. L. .	40	Do. .	Do.
Do. .	(58) Mr. M. D. Varaich	Do.	M. L. .	80	21st December 1937.	30 years.
Santal Parganas.	(59) Babu Rameshwar Marwari Darji.	Coal	M. L. .	5	1st April 1937	2 years.
Do. .	(60) Babu Ganga Ram Marwari.	Do.	M. L. .	1·82	Do. .	Do.
Do. .	(61) Babu Jagannath Bhagat.	Do.	M. L. .	2	Do. .	1 year.
Do. .	(62) Do. . .	Do.	M. L. .	5	Do. .	2 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BIHAR—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Santal Parganas.	(63) Babu Subodh Chandra De.	Coal	M. L.	0·98	1st April 1937	2 years.
Do.	(64) Do.	Do.	M. L.	4·05	Do.	Do.
Do.	(65) Babu Bansi Ram Marwari.	Do.	M. L.	5	Do.	Do.
Do.	(66) Do.	Do.	M. L.	1·62	Do.	Do.
Do.	(67) Do.	Do.	M. L.	0·33	Do.	Do.
Do.	(68) Do.	Do.	M. L.	1·90	Do.	Do.
Singhbhum	(69) Babu Raghuram Marwari.	Chromite	P. L.	844·80	22nd March 1937.	1 year.
Do.	(70) Babu Madan Gopal Rungta.	Manganese	P. L.	725	1st April 1937	Do.

BOMBAY.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Belgaum	(71) The Hon. Mr. Narayandas Girdharidas.	Manganese	P. L.	97·5	20th October 1937.	1 year.
Kanara	(72) Do.	Do.	P. L.	1,937·15	19th November 1936.	Do.
Do.	(73) Messrs. Killick Nixon & Co.	Do.	P. L.	290	12th February 1937.	Do.

CENTRAL PROVINCES AND BERAR.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(74) Messrs. B. P. Byramjee & Co., Nagpur.	Manganese	M. L.	322	28th January 1937.	5 years.
Do.	(75) Do.	Do.	M. L.	2	6th February 1937.	Do.
Do.	(76) Mr. Amritlal P. Trivedi of Balaghat.	Do.	M. L.	42	25th March 1937.	30 years.
Do.	(77) Mr. Kanhaiyalal, Advocate of Balaghat.	Do.	M. L.	162	27th September 1937.	10 years.
Do.	(78) R. B. Bansilal Abirchand, Mining Syndicate.	Do.	M. L.	17	25th January 1937.	Do.
Do.	(79) Mr. Amritlal P. Trivedi, Balaghat.	Do.	M. L.	22	23rd November 1937.	Do.
Do.	(80) Mr. Diwanchand Jiwar of Balaghat.	Do.	P. L.	32	5th March 1937.	1 year.
Do.	(81) Messrs. Oke Bros., Nagpur.	Do.	P. L.	26	8th March 1937.	Do.
Do.	(82) The Central Provinces Manganese Ore Co., Nagpur.	Do.	P. L.	45	25th March 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(83) R. B. Seth Gowardhandas, Tumsar.	Manganese . .	P. L. .	70	29th July 1937.	1 year.
Do. .	(84) Seth Mohanlal Jagannath, Tumsar.	Do. . . .	P. L. .	71	2nd August 1937.	Do.
Do. .	(85) Messrs. Cheniram Jesraj, Nagpur.	Do. . . .	P. L. .	150	Do. .	Do.
Do. .	(86) Mr. Diwanchand Jiwar, Balaghat.	Do. . . .	P. L. .	60	4th August 1937.	Do.
Do. .	(87) Rai Bahadur Seth Gowardhan Das of Tumsar.	Do. . . .	P. L. .	188	6th August 1937.	Do.
Do. .	(88) Do. . .	Do. . . .	P. L. .	103	14th August 1937.	Do.
Do. .	(89) Do. . .	Do. . . .	P. L. .	21	16th August 1937.	Do.
Do. .	(90) Mr. Shreeram Seth, Tumsar.	Do. . . .	P. L. .	102	Do. .	Do.
Do. .	(91) Rai Bahadur Seth Gowardhan Das of Tumsar.	Do. . . .	P. L. .	74	24th August 1937.	Do.
Do. .	(92) Do. . .	Do. . . .	P. L. .	8	26th August 1937.	Do.
Do. .	(93) Mr. R. P. Mudliar, Balaghat.	Do. . . .	P. L. .	33	6th September 1937.	Do.
Do. .	(94) Mr. Shreeram Seth, Tumsar.	Do. . . .	P. L. .	57	14th September 1937.	Do
Do. .	(95) Messrs. Oke Brothers, Nagpur.	Copper . . .	P. L. .	134	15th September 1937.	Do.
Do. .	(96) Mr. Shreeram Seth, Tumsar.	Manganese . .	P. L. .	140	Do. . .	Do.
Do. .	(97) Mr. K. A. Chiranjiva Rao, Kamptee.	Do. . . .	P. L. .	78	20th September 1937.	Do.
Do. .	(98) Mr. Diwanchand Jiwar, Balaghat.	Do. . . .	P. L. .	81	Do. .	Do.
Do. .	(99) Messrs. Cheniram Jesraj, Nagpur.	Do. . .	P. L. .	95	1st October 1937.	Do.
Do. .	(100) Mr. Shreeram Seth, Tumsar.	Do. . . .	P. L. .	68	6th October 1937.	Do.
Do. .	(101) Messrs. Cheniram Jesraj, Nagpur.	Do. . . .	P. L. .	75	9th October 1937.	Do.
Do. .	(102) Mr. K. A. Chiranjiva Rao, Kamptee.	Do. . . .	P. L. .	54	11th October 1937.	Do.
Do. .	(103) Mr. M. G. Rungta, Chaibasa.	Do. . . .	P. L. .	60	15th October 1937.	Do.
Do. .	(104) Mr. Shreeram Seth, Tumsar . .	Do. . .	P. L. .	88	Do. .	Do.

P. L. = *Prospecting License.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(105) Messrs. Harish Chandra and Bhadulal Tumsar.	**Manganese** . .	P. L. .	8	20th October 1937.	1 year.
Do. .	(106) R. B. Seth Gowardhan Das, Tumsar.	Do. . . .	P. L. .	76	22nd October 1937.	Do.
Do. .	(107) Do. . .	Do. . . .	P. L. .	56	Do. .	Do.
Do. .	(108) Do. . .	Do. . . .	P. L. .	59	25th October 1937.	Do.
Do. .	(109) Do. . .	Do. . . .	P. L. .	68	26th October 1937.	Do.
Do.	(110) Mr. Shreeram Seth, Tumsar.	Do. . . .	P. L. .	1	8th November 1937.	Do.
Do. .	(111) Messrs. Pacific Minerals, Ltd., Calcutta, Branch Office, Balaghat.	Do. . . .	P. L. .	144	9th November 1937.	Do.
Do. .	(112) Rai Bahadur Seth Gowardhan Das, Tumsar.	Do. . . .	P. L. .	46	Do. .	Do.
Do. .	(113) Mr. M. G. Rungta. Chaibasa.	Do. . . .	P. L. .	27	Do. .	Do.
Do. .	(114) Messrs. Pacific Minerals, Ltd., Calcutta, Branch Office, Balaghat.	Do. . .	P. L. .	69	10th November 1937.	Do.
Do. .	(115) Mr. M. G. Rungta, Chaibasa.	Do. . . .	P. L. .	122	12th November 1937.	Do.
Do. .	(116) Mr. Shreeram Seth, Tumsar.	Do. . . .	P. L. .	129	17th November 1937.	Do.
Do. .	(117) Rai Bahadur Seth Gowardhandas, Tumsar.	Do. . . .	P. L. .	41	18th December 1937.	Do.
Do. .	(118) Do. . .	Do. . .	P. L. .	11	26th November 1937.	Do.
Do. .	(119) Do. . .	Do. . . .	P. L. .	57	29th November 1937.	Do.
Do. .	(120) Do. . .	Do. . . .	P. L. .	67	11th December 1937.	Do.
Do. .	(121) Mr. Shreeram Seth, Tumsar.	Do. . . .	P. L. .	37	14th December 1937.	Do.
Do. .	(122) Mr. S. Abidun, Engineer, Nagpur.	Do. . . .	P. L. .	27	16th December 1937.	Do.
Betul . .	(123) C. P. Syndicate, Ltd., Nagpur.	Coal . . .	P. L. .	1,028	22nd February 1937.	Do.
Do. . .	(124) Mr. Jagannath Ramdayal, Hirdagarh.	Do. . . .	P. L. .	426	17th March 1937.	Do.
Do. . .	(125) Mr. B. R. Goenka, Nagpur.	Limestone . .	P. L. .	10	16th July 1937.	Do.

P. L.=*Prospecting License.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Betul	(126) Kanhan Valley Coal Co., Ltd.	Coal	P. L.	78	2nd April 1937.	1 year.
Do.	(127) Do.	Do.	P. L.	585	27th May 1937	Do.
Do.	(128) Mr. P. J. Registrar, Nagpur.	Do.	P. L.	1,680	5th June 1937	Do.
Do.	(129) Kanhan Valley Coal Co., Ltd.	Do.	P. L.	432	28th April 1937.	Do.
Do.	(130) Do.	Do.	P. L.	368	22nd April 1937.	Do.
Do.	(131) Do.	Do.	P. L.	129	8th March 1937.	Do.
Do.	(132) Do.	Do.	P. L.	119	22nd October 1937.	Do.
Do.	(133) Mr. B. R Goenka, Nagpur.	Do.	P. L.	310	16th July 1937	Do.
Do.	(134) Kanhan Valley Coal Co., Ltd., Nagpur.	Do.	P. L.	69	26th February 1937.	Do.
Do.	(135) Mr. Pandurang Tukaram Patrikar, Betul.	Red oxide of iron and ochre.	P. L.	107	1st March 1937.	Do.
Do.	(136) Mr. H. K. Nag, Chasnalla.	Coal	P. L.	1,380	8th November 1937.	Do.
Do.	(137) Mr. B. R. Goenka, Nagpur.	Do.	M. L.	123	21st July 1937.	30 years.
Do.	(138) Do.	Do.	M. L.	583	16th September 1937.	Do.
Bhandara	(139) Messrs. Ganpatsao Dhanpatsao.	Manganese ore	P. L.	61	19th May 1936.	1 year.
Do.	(140) Messrs. Oke Brothers.	Do.	P. L.	38	18th June 1937.	Do.
Do.	(141) Do.	Do.	P. L.	64	3rd April 1937.	Do.
Do.	(142) Mr. Shriram Seth	Do.	P. L.	36	30th September 1937.	Do.
Do.	(143) Messrs. Haris Chandra Bhadulal.	Do.	P. L.	76	18th November 1937.	Do.
Do.	(144) Rai Bahadur Seth Govardhandass.	Do.	P. L.	1	26th July 1937.	Do.
Do.	(145) Messrs. Harischandra Bhadulla.	Do.	P. L.	84	10th July 1937.	Do.
Do.	(146) Mr. K. A. Chironjivarao.	Do.	P. L.	331	1st October 1937.	Do.
Do.	(147) Do.	Do.	P. L.	10	18th August 1937.	Do.
Do.	(148) Do.	Do.	P. L.	62	12th September 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(149) Mr. K. A. Chironjivarao.	Manganese ore .	P. L. .	30	30th July 1937.	1 year.
Do. .	(150) Messrs. Ganpatsao Dhanpatsao.	Do. . .	P. L. .	39	9th October 1937.	Do.
Do.	(151) Mr. M. D'Costa .	Do. . .	P. L. .	5	17th July 1937.	Do.
Do. .	(152) Do. . .	Do. . .	P. L. .	54	26th July 1937.	Do.
Do. .	(153) Mr. Mohanlal Jagannath.	Do. . .	P. L. .	24	28th October 1937.	Do.
Do. .	(154) Do. . .	Do. . .	P. L. .	90	23rd October 1937.	Do.
Do. .	(155) Mr. Bansidhar Ramnivas Goenka.	Do. . .	P. L. .	105	17th August 1937.	Do.
Do. .	(156) Do. . .	Do. . .	P. L. .	35	Do. .	Do.
Do. .	(157) Mr. Shriram Seth	Do. . .	P. L. .	27	6th August 1937.	Do.
Do. .	(158) Messrs. Harischandra Bhadulal.	Do. . .	P. L. .	662	5th October 1937.	Do.
Do. .	(159) Mr. Mohanlal Jagannath.	Do. . .	P. L. .	75	28th October 1937.	Do.
Do. .	(160) Mr. M. D'Costa .	Do. . .	P. L. .	1	31st August 1937.	Do.
Do. .	(161) Mr. Shriram Seth	Do. . .	P. L. .	23	2nd September 1937.	Do.
Do. .	(162) Do. . .	Do. . .	P. L. .	34	24th September 1937.	Do.
Do. .	(163) Mr. Mohanlal Jagannath.	Do. . .	P. L. .	136	10th September 1937.	Do.
Do. .	(164) Do. . .	Do. . .	P. L. .	34	20th August 1937.	Do.
Do. .	(165) Rai Bahadur Gowardhandas.	Do. . .	P. L. .	42	22nd October 1937.	Do.
Do. .	(166) Do. . .	Do. . .	P. L. .	47	28th September 1937.	Do.
Do. .	(167) Messrs. Fatechand & Sons.	Do. . .	P. L. .	101	23rd October 1937.	Do.
Do. .	(168) Mr. Shriram Seth	Do. . .	P. L. .	20	9th October 1937.	Do.
Do. .	(169) Mr. M. D'Costa .	Do. . .	P. L. .	18	28th October 1937.	Do.
Do. .	(170) Messrs. Harischandra Bhadulal.	Do. . .	P. L. .	69	9th October 1937.	Do.
Do. .	(171) Mr. Shriram Seth	Do. . .	P. L. .	18	8th November 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara	(172) Messrs. Harischandra Bhadulal.	Manganese ore	P. L.	238	9th October 1937.	1 year.
Do.	(173) Do.	Do.	P. L.	6	Do.	Do.
Do.	(174) Mr. Shriram Seth	Do.	P. L.	33	20th October 1937.	Do.
Do.	(175) Do.	Do.	P. L.	54	17th October 1937.	Do.
Do.	(176) Messrs. Fatechand & Sons.	Do.	P. L.	9	28th September, 1937.	Do.
Do.	(177) R. B. Seth Gowardhandass.	Do.	P. L.	62	Do.	Do.
Do.	(178) Messrs. Harischandra Bhadulal.	Do.	P. L.	5	2nd October 1937.	Do.
Do.	(179) Do.	Do.	P. L.	33	17th Novem- 1937.	Do.
Do	(180) Mr. G. L. Jaipuria.	Do.	P. L.	8	24th November 1937.	Do.
Do.	(181) Mr. Nandlal	China clay	P. L.	179	18th September 1937.	Do.
Do.	(182) Do.	Red oxide of iron	P. L.	12	18th October 1937.	Do.
Do.	(183) Shri Bajarang Mineral Co.	Red oxide of iron and red and yellow ochre.	Q. L.	16	7th March 1937.	10 years.
Do.	(184) Shri Kesho Mineral Co., C. P.	White and china clay.	Q. L.	64	9th August 1937.	Do.
Do.	(185) Shri Bajrang Co.	Red oxide of iron and red and yellow ochre.	Q. L.	53	11th December 1937.	Do.
Do.	(186) Messrs. Oke Brothers.	Manganese ore	M. L.	37	19th August 1937.	15 years.
Do.	(187) Nagpur Bhandara Manganese Ore Co.	Do.	M. L.	134	23rd November 1937.	30 years.
Do.	(188) Rai Bahadur Seth Gawardhandass.	Do.	M. L.	13	23rd August 1937.	5 years.
Do.	(189) Do.	Do.	M. L.	4	Do.	Do.
Bilaspur	(190) Messrs. Tata Iron & Steel Co.	Limestone	P. L.	581	30th April 1937.	1 year.
Do.	(191) Mr. Mulji Jagmal.	Manganese	P. L.	186	29th November 1937.	Do.
Do.	(192) Do.	Clay	Q. L.	4	16th January 1937.	4 years.
Do.	(193) Mr Dhanraj Wason.	Do.	Q. L.	3	2nd September 1937.	5 years.
Do.	(194) Sirder Uttamsingh.	Do.	Q. L.	7	24th February 1937.	10 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bilaspur .	(195) Mr. Jairam Valji	Limestone . .	Q. L. .	15	13th August 1937.	10 years.
Chanda .	(196) Messrs. Birla Brothers, Ltd., Bombay.	Coal . . .	M. L. .	22	3rd May 1937	13 years.
Do. . .	(197) Mr. Peshora Sing Sial, Proprietor, Majri Colliery.	Do. . . .	P. L. .	237	1st March 1937.	1 year.
Do. . .	(198) Lala Budhulal, Mines Proprietor, Hirdagarh.	Do. . .	P. L. .	983	20th September 1937.	Do.
Do. . .	(199) The Jamai Majri Coal Co., Ltd., Chhindwara.	Do. . . .	P. L. .	325	20th August 1937.	Do.
Do. .	(200) Mr. Muhammad Hussain R. Hashambhoy, General Merchant, Chanda.	Ochre . . .	P. L. .	28	9th February 1937.	Do.
Do. . .	(201) Mr. Dattatraya Gopal Patri, Bhanapeth, Chanda.	Clay . .	P. L. .	30	13th October 1937.	Do.
Chhindwara	(202) H. S. Zahir-ud-din of Chhindwara.	Coal . .	M. L. .	81	25th March 1937.	30 years.
Do. .	(203) Mr. M. D'Costa, Nagpur.	Manganese .	P. L. .	102	10th February 1937.	Do.
Do. .	(204) Do. . .	Do. . . .	P. L. .	44	Do. .	Do.
Do. .	(205) Major J. C. Mauce, Jubbulpore.	Zeolites . . .	P. L. .	146	18th March 1937.	Do.
Do. .	(206) Haji Syed Zahir-ud-din.	Coal . . .	P. L. .	279	25th March 1937.	Do.
Do. .	(207) Do. .	Do. . . .	P. L. .	271	Do. .	. .
Do. .	(208) C. P. Syndicate, Ltd.	Do. . . .	P. L. .	524	22nd October 1937.	1 year.
Do. .	(209) Do. .	Do. . . .	P. L. .	172	Do. .	Do.
Do. .	(210) Do. .	Do. . . .	P. L. .	146	Do. .	Do.
Do. .	(211) Do.	Do. . . .	P. L. .	45	Do. .	Do.
Do. .	(212) Mr. M. D'Costa, Nagpur.	Manganese . .	P. L. .	81	26th October 1937.	Do.
Do. .	(213) Haji Syed Zahir-ud-din, Chhindwara.	Coal . . .	P. L. .	242	1st November 1937.	Do.
Do. .	(214) Wasudio Shrawsan Dalal.	Do. . . .	P. L.	783	2nd December 1937.	Do.
Drug . .	(215) Mr. Krishnarao	Limestone . .	Q. L. .	12	30th August 1937.	3 years.
Jubbulpore .	(216) Mr. Peshora Singh Sial, Chhindwara.	Soapstone .	Q. L. .	45	23rd October 1937.	10 years.
Do. .	(217) Messrs. Dyers, Stone Lime Co., Ltd., Katni.	Limestone . .	Q. L. .	53	15th November 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jubbulpore .	(218) Messrs. Burn & Co., Ltd., Jubbulpore.	Clay . . .	Q. L. .	20	23rd August 1937.	10 years.
Do. .	(219) Mr. Ramchandra Gour, Katni.	Limestone . .	P. L. .	51	Do. .	1 year.
Do. .	(220) Messrs. Shankar Prasad Badri Prasad, Katni.	Do. . . .	P. L. .	394	26th January 1937.	Do.
Do. .	(221) Mr. Kedar Prasad, Katni.	Do. . . .	P. L. .	35	12th October 1937.	Do.
Do. .	(222) Do. .	Antimony . .	P. L. .	53	6th September 1937.	Do.
Do. .	(223) The Associated Cement Co., Bombay.	Clay . . .	P. L.	124	12th July 1937.	Do.
Do. .	(224) Do. .	Do. . . .	P. L. .	341	29th September 1937.	Do.
Do. .	(225) Mr. Kedar Prasad, Katni.	Red oxide of iron .	P. L. .	26	7th January 1937.	Do.
Do. .	(226) Mr. Hari Prashad Pathak, Katni.	Soapstone . .	P. L.	61	21st March 1937.	Do.
Do. .	(227) Messrs. Burn & Co., Ltd., Jubbulpore.	Felspar and clay .	P. L. .	119	1st September 1937.	Do.
Do. .	(228) Seth Gangadhar Rameshwardass, Katni.	Bauxite . .	P. L.	156	19th July 1937	D .
Do. .	(229) Do. .	Do. . . .	P. L. .	179	25th July 1937	Do.
Do. .	(230) D. B. Ballabdass Mannoolal and Kanahiyalal.	Coal . . .	P. L. .	649	14th August 1937.	Do.
Do. .	(231) Mr. Kedar Prasad Agarwal, Katni.	Bauxite . . .	P. L. .	52	6th September 1937.	Do.
Do. .	(232) Seth Gangadhar Rameshwardass, Katni.	Do. . .	P. L. .	76	3rd September 1937.	Do.
Do. .	(233) Mr. Kedar Prasad, Katni.	Barytes . . .	P. L. .	34	3rd August 1937.	Do.
Do. .	(234) Messrs. C. L. Pathak & Sons, Katni.	Do. . . .	P. L. .	37	13th August 1937.	Do.
Do. .	(235) Mr. Kedar Prashad Agarwal, Katni.	Do. . . .	M. L. .	25	3rd July 1937	10 years.
Do. .	(236) Mr. Kedar Prashad, Katni.	Limestone . .	Q. L. .	3	20th October 1937.	Do.
Do. .	(237) Mr. Nasarwanju	Do. . .	Q. L. .	1	23rd August 1937.	Do.
Do. .	(238) Seth Gangadhar Rameshwardass, Katni.	Soapstone . .	Q. L. .	4	23rd November 1937.	Do.
Do. .	(239) Messrs. Burn & Co., Ltd., Jubbulpore.	Clay . . .	Q. L. .	1	Do. .	Do.

P. L.—*Prospecting License.* M. L.—*Mining Lease.* Q. L.—*Quarry Lease.*

CENTRAL PROVINCES AND BERAR—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(240) Mr. B. R. Goenka, Nagpur.	Manganese . .	P. L. .	56	29th September 1937.	1 year.
Do. .	(241) Do. .	Do. . .	P. L. .	44	16th September 1937.	Do.
Do. .	(242) Rai Sahib Seth Phulchand, Kamptee.	Do. . .	P. L. .	1	7th August 1937.	Do.
Do. .	(243) Do. .	Do. . .	P. L. .	15	23rd July 1937	Do.
Do. .	(244) Seth Mohan Lal Jagannath, Tumsar.	Do. . .	P. L. .	32	9th November 1937.	Do.
Do. .	(245) Bhawanji, Ramtek.	Do. . .	P. L. .	187	6th December 1937.	Do.
Do. .	(246) Mr. K. A. Chiranjiwa Rao, Kamptee.	Do. . .	P. L. .	107	Do. .	Do.
Do. .	(247) Rai Bahadur Seth Govardhan Das, Tumsar.	Do. . .	P. L. .	20	15th December, 1937.	Do.
Do. .	(248) Do. .	Do. . .	P. L. .	78	10th December 1937.	Do.
Do. .	(249) The Hon'ble Sir M. B. Dadabhoy.	Coal . . .	P. L. .	142	27th November 1937.	Do.
Do. .	(250) Do. .	Do. . . .	P. L. .	283	6th December 1937.	Do.
Do. .	(251) Do. .	Do. . . .	P. L. .	314	13th December 1937.	Do.
Do. .	(252) Messrs. Dhanju Deoji and Sons.	Manganese . .	P. L. .	105	15th December 1937.	Do.
Do. .	(253) Do. .	Do. . .	P. L. .	68	10th December.	Do.
Do. .	(254) Shree Ram Seth, Tumsar.	Do. . .	P. L. .	66	13th October	Do.
Do. .	(255) Do. .	Do. . .	P. L. .	835	Do. .	Do.
Do. .	(256) Do. .	Do. . .	P. L. .	221	24th November 1937.	Do.
Do. .	(257) Seth Mohanlal Jagannath.	Do. .	P. L. .	108	9th November 1937.	Do.
Do. .	(258) Mr. K. A. Chiranjivarao.	Do. . .	P. L. .	263	13th December 1937.	Do.
Do. .	(259) Mr. Shamji Narainji, Ramtek.	Do. . .	P. L. .	92	9th December 1937.	Do.
Do. .	(260) Seth Mohanlal Jagannath.	Do. . .	P. L. .	70	24th December 1937.	Do.
Do. .	(261) Mr. B. R. Goenka	Do. . .	P. L.	235	6th December 1937.	Do.
Do. .	(262) R. S. Seth Phulchand.	Do. . .	P. L. .	110	24th November 1937.	Do.
Do. .	(263) R. B. Seth Govardhan Das.	Do. . .	P. L. .	54	Do .	Do.

P. L.=*Prospecting License*.

CENTRAL PROVINCES AND BERAR—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(264) Khan Bahadur, M. E. R. Malak.	Clay . .	Q. L. .	20	1st September 1937.	10 years.
Do. .	(265) Mr. C. B. Parakh, Nagpur.	Do. . . .	Q. L. .	20	15th February 1936.	Do.
Do. .	(266) Messrs. Oke Brothers, Nagpur.	Building stone .	Q. L. .	8	27th July 1937	Do.
Do. .	(267) The Hon'ble Sir M. B. Dadabhoy.	Manganese . .	M. L. .	2	18th January 1937.	5 years.
Do. .	(268) Mr. Muhammed Sayad, Nagpur.	Clay . . .	Q. L. .	5	21st July 1937	Do.
Do. .	(269) Mr. B. R. Goenka, Nagpur.	Manganese . .	M. L. .	138	1st September 1937.	10 years.
Do. .	(270) Seth Mohanlal Jagannath.	Do. . .	M. L. .	82	17th December 1937.	Do.
Raipur .	(271) Mr. Ishwardas, Contractor	Clay	Q. L. .	8	12th January 1937.	Do.
Do. .	(272) Mr. Mithoomal, Railway Contractor.	Do. . . .	Q. L. .	13	4th August 1937.	5 years.
Do. .	(273) Do. .	Limestone . .	P. L. .	2	14th December 1937.	1 year.
Yeotmal .	(274) Mr. Shaikh Kasam, Nagpur.	Do. . .	Q. L. .	28	1st October 1938.	10 years.
Do. .	(275) Mr. A. H. Wasudeorao, Nagpur.	Do. . .	Q. L. .	7	1st December 1938.	Do.
Do. .	(276) Do. .	Do .	P. L. .	68	20th April 1937.	1 year.
Do .	(277) Mr. Timbakrao Zamaji Thakre, Rajpur.	Do. . .	Q. L. .	9	2nd September 1937.	10 years.
Do. .	(278) Mr. F. X. Rebello, Nagpur.	Do. . .	P. L. .	40	21st May 1937	1 year.
Do. .	(279) Do. .	Do. . .	Q. L. .	3	25th August 1937.	10 years.
Do. .	(280) Do. .	Do. . .	P. L .	31	21st September 1937.	1 year.
Do. .	(281) Do .	Do. . .	P. L. .	34	7th August 1937.	Do.

MADRAS.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Anantapur .	(282) Mr. J. L. Chapman.	Steatite . .	P. L. .	48·16	*	1 year.
Do. .	(283) Mr. T. Dasaratharami Reddi.	Barytes . . .	P. L. .	22·12	15th August 1937.	Do.
Do. .	(284) Mr. P. Sesha Reddi.	Do. . . .	P. L. .	10·42	24th January 1937.	Do.
Do. .	(285) Mr. Vishnu Nimbkar.	Do. . . .	P. L. .	22·51	5th February 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*
Q. L. = *Quarry License.*
* License registered in 1937.

MADRAS—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Anantapur	(286) Mr. P. Venkayya	Asbestos, chromite and diamonds.	P. L.	25·98	*	1 year.
Do.	(287) Mr. Vishnu Nimbkar.	Barytes	P. L.	59·96	5th February 1937.	Do.
Bellary	(288) Mr. G. Chennappa	Manganese	P. L.	337·0	30th June 1937.	Do.
Do.	(289) Mr. K. Muhammad Bashur.	Do.	P. L.	601·0	10th July 1937	Do.
Do.	(290) Mr. Khan Sahib K. Abdul Hye Sahib.	Do.	P. L.	226·88	17th June 1937.	Do.
Cuddapah	(291) Mr. T. H. B. Tiffin.	Barytes	P. L.	54·59	19th December 1936.	Do.
Do.	(292) Do.	Do.	P. L.	50·21	2nd August 1937.	Do.
Do	(293) Mr. Syed Abdul Khader Sahib.	Asbestos	P. L.	138·51	12th March 1937.	Do.
Do.	(294) Do.	Barytes	P. L.	63·87	15th July 1937	Do.
Do.	(295) Mr. Narayandas Girdhardas.	Galena	P. L.	34·0	27th February 1937.	Do.
Do.	(296) Mr. S. S. Guzdar	Asbestos	P. L.	179·69	30th September 1936.	Do.
Do.	(297) Mr. Narayandas Girdhardas.	Lead, silver, antimony and zinc.	P. L.	236·0	23rd October 1936.	Do.
Do.	(298) Mr. A. Krishnappa.	Asbestos	P. L.	20·80	5th June 1936	Do.
Do.	(299) Do.	Barytes	P. L.	58·50	29th August 1936.	Do.
Do.	(300) Mr. Narayandas Girdhardas.	Asbestos	P. L.	514·76	23rd October 1936.	Do.
Do.	(301) Mr. T. H. B. Tiffin.	Barytes	P. L.	20·48	23rd June 1937.	Do.
Do.	(302) Mr. B. P. Sesha Reddi.	Do.	P. L.	8·70	21st June 1937.	Do.
Do.	(303) Do.	Do.	P. L.	5·59	Do.	Do.
Do.	(304) Mr. T. H. B. Tiffin.	Do.	P. L.	21·80	23rd June 1937.	Do.
Do.	(305) Mr. Narayandas Girdhardas.	Galena	P. L.	609·50	25th February 1937.	Do.
Do.	(306) Mr. B. P. Sesha Reddi.	Barytes	P. L.	5·93	15th July 1937	Do.
Do.	(307) Do.	Do.	P. L.	28·29	15th October 1937.	Do.
Do.	(308) Mr. Venkadara Redda Rangaswami Chetti.	Do.	P. L.	86·50	9th November 1937.	Do.
Do.	(309) Mr. S. S. Guzdar	Asbestos	P. L.	45·25	25th March 1937.	Do.

P. L. = *Prospecting License.*
* License registered in 1937.

MADRAS—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cuddapah	(310) Mr. Syed Abdul Khader Sahib.	Barytes	P. L.	3·7	19th August 1937.	1 year.
Do.	(311) Mr. B. P. Sesha Reddi.	Do.	P. L.	86·70	30th July 1937	Do.
Do.	(312) Messrs. Punt & Rao.	Iron ore	P. L.	65·50	11th October 1937.	Do.
Do.	(313) Mr. Narayandas Girdhardas.	Lead, silver, copper, zinc and antimony.	P. L.	162·10	29th May 1937	Do.
Do.	(314) Do.	Do.	P. L.	344·87	30th July 1937	Do.
Do.	(315) Mr. A. Krishnappa.	Iron-ore	P. L.	13·00	22nd December 1937.	Do.
Do.	(316) Mr. S. S. Guzdar	Barytes	M. L.	145·48	1st October 1936.	25 years.
Do.	(317) Do.	Do.	M. L.	180·2	1st July 1937	30 years.
Do.	(318) Mr. K. Balakrishna Nayudu.	Aluminium silicate	M. L.	18·0	1st April 1937	Do.
Kurnool	(319) Mr. B. P. Sesha Reddi.	Barytes	P. L.	27·52	26th January 1937.	1 year.
Do.	(320) Do.	Steatite	P. L.	5·00	26th March 1937.	Do.
Do.	(321) Mr. Narayandas Girdhardas.	Diamond	P. L.	932·35	13th February 1937.	Do.
Do.	(322) Mr. S. S. Guzdar	Barytes	P. L. (Renewal).	10·24	6th November 1936.	Do.
Do.	(323) Mr. Narayandas Girdhardas.	Copper-ore	P. L.	63·44	22nd April 1937.	Till 5th August, 1937.
Do.	(324) Do.	Diamond	P. L.	73·85	13th July 1937	1 year.
Do.	(325) Mr. Bepari Abdul Nabi Sahib.	Barytes	P. L.	11·00	8th November 1937.	Do.
Do.	(326) Mr. B. P. Sesha Reddi.	Do.	P. L.	13·00	9th October 1937.	Do.
Do.	(327) Do.	Do.	P. L.	22·00	9th December 1937.	Do.
Do.	(328) Mr. Narayandas Girdhardas.	Iron and copper pyrites.	P. L.	200·20	11th November 1927.	Do.
Nellore	(329) Mr. Vakati Sanjivi Chetti.	Mica	M. L.	60·35	15th June 1937.	30 years.
Do.	(330) Do.	Do.	M. L.	3·00	14th September 1937.	Do.
Do.	(331) Messrs. T. Rami Reddi and M. Dasaratharami Reddi.	Do.	M. L.	0·56	26th September 1937.	Do.
Do.	(332) Mr. P. Dasaratharami Reddi.	Do.	M. L.	47·44	4th December 1937.	Do.
Do.	(333) Mr. K. Rami Reddi.	Do.	M. L.	91·62	25th November 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(334) Mr. Thummala Sesha Reddi.	Mica	P. L. .	49·24	4th February 1937.	1 year.
Do. .	(335) Mr. T. Venkatasubbiah Nayudu.	Do.	P. L. .	16·99	27th February 1937.	Do.
Do. .	(336) Mr. V. G. Krishna Rao.	Do.	P. L. .	6·30	17th May 1937	Do.
Do. .	(337) Mr. Vekati Sanjivi Chetti.	Do.	P. L. .	13·20	25th August 1937.	Do.
Salem .	(338) Mr. Krishna Nimbkar.	Corundum . .	P. L. .	520·74	19th April 1937.	Do.
Do. .	(339) Mr. Narayandas Girdhardas.	Magnesite and chromite.	P. L. .	17·47	27th April 1937.	Do.
Do. .	(340) Mr. S. K. Ramachandar.	Magnesite, chromite, garnets and iron.	P. L. .	150·00	12th June 1937.	Do.
Do. .	(341) Mr. Narayandas Girdhardas.	Gold and silver .	P. L. (Renewal).	64·36	13th December 1936.	Do.
Do. .	(342) Mr. Narayandas Girdhardas.	Magnesite and chromite.	P. L. .	36·85	8th July 1937	Do.
Tanjore .	(343) Messrs. C. Manavalan and K. H. Chambers.	Black sand, ilmenite, monazite, zircon, rutile and garnet.	P. L. .	283·97	10th July 1937	Do.

NORTH-WEST FRONTIER PROVINCE.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kohat . .	(344) Indo-Burma Petroleum Co., Ltd., through Managing Agents, Steel Brothers & Co.	Natural Petroleum .	P. L. . (Renewal).	3,627	18th October 1935.	1 year.
Do. . .	(345) Do. .	Do. .	P. L. (Renewal).	800	18th October 1935.	Do.

ORISSA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Sambalpur .	(346) Babu Basanta Kumar Sanyal.	Red oxide of iron	M. L.	71·49	10th August 1937.	5 years.

PUNJAB.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Attock .	(347) The Attock Oil Co., Ltd., Rawalpindi.	Mineral oil . .	P. L.	10,000	26th August 1937.	1 year.
Do. .	(348) Do. .	Do. . . .	P. L. .	4,800	11th September 1937.	Do.
Do. .	(349) M. Allah Din, Contractor of Ratucha.	Coal . .	P. L. .	1,347	14th September 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease*

PUNJAB—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum	(350) Messrs. Wah Stone Lime Quarry Ltd. and P. Gian Chand.	Coal	M. L.	126·4	17th May 1937	30 years.
Do.	(351) Bakhshi Jiwan Mal.	Do.	M. L.	100	20th February 1936.	15 years.
Do.	(352) Messrs. Chaman Lal Bhola and Sons.	Do.	M. L.	160	1st November 1937.	10 years.
Do.	(353) L. Ram Lal of Dandot.	Do.	P. L.	66	1st May 1937	1 year.
Do.	(354) The Chakwal Brick Company, Chakwal.	Do.	P. L.	272	1st August 1937.	Do.
Do.	(355) The Attock Oil Co., Ltd., Rawalpindi.	Petroleum	P. L.	1,560	23rd February 1937.	Do.
Do.	(356) Do.	Do.	P. L.	3,840	Do.	Do.
Do.	(357) The Chakwal Brick Company and Bakhshi Guru Datt.	Coal	P. L.	145·45	21st April 1937	Do.
Do.	(358) The Chakwal Brick Company.	Do.	P. L.	166·92	15th May 1937	Do.
Do.	(359) Lala Kalyan Dass	Do.	P. L.	66	2nd September 1937.	Do.
Do.	(360) The Attock Oil Co., Ltd., Rawalpindi.	Petroleum	P. L.	10,240	5th February 1937.	Do.
Do.	(361) P. Gian Chand & Bhai Hazura Mall.	Coal	P. L.	151·5	1st July 1937	Do.
Do.	(362) Sant L. Ram Kapur.	Do.	P. L.	117·25	18th June 1937.	Do.
Do.	(363) Do.	Do.	P. L.	63	19th July 1937	Do.
Do.	(364) L. Ram Autar of Khewra.	Do.	P. L.	113·60	15th November 1937.	Do.
Do.	(365) S. Jai Ram Singh, Proprietor, Himalaya Coal Coy., Rawalpindi.	Do.	P. L.	179·06	1st June 1937	Do.
Do.	(366) Do.	Do.	P. L.	100	2nd August 1937.	Do.
Do.	(367) S. Jai Ram Singh, Proprietor, Coal Coy., Rawalpindi.	Do.	P. L.	156·8	15th October 1937.	Do.
Do.	(368) Do.	Do.	P. L.	54·4	15th September 1937.	Do.
..	(369) Do.	Do.	P. L.	81·32	30th November 1937.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

PUNJAB—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum .	(370) Sh. Abdul Aziz of Chakwal.	Coal	P. L. .	862·5	14th September 1937.	1 year.
Do. . .	(371) Chakwal Brick Company, Chakwal.	Do.	P. L. .	120·3	1st February 1937.	Do.
Mianwali .	(372) L. Lal Chand Kalra.	Do.	M. L. .	966·26	27th October 1937.	30 years.
Do. .	(373) Do. .	Do.	M. L. .	2,028·6	30th October 1937.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

SUMMARY.

Province.	Prospecting Licenses.	Mining Leases.	Quarry Leases.	Total for each Province.
Ajmer-Merwara	42	4	..	46
Assam	1	..	..	1
Baluchistan	..	4	..	4
Bihar	2	17	..	19
Bombay	3	..	..	3
Central Provinces	165	18	25	208
Madras	54	8	..	62
North-West Frontier Province	2	..	..	2
Orissa	..	1	..	1
Punjab	22	5	..	27
Total of each kind and grand total .	291	57	25	373
Total for 1937 .	204	51	32	287
Burma . . . . 1937 .	271	46	..	317
Burma . . . . 1936 .	227	17	..	244

TABLE 55.—*Prospecting Licenses and Mining Leases granted in Ajmer-Merwara during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
PROSPECTING LICENSES.			
Ajmer	12	21·40	Mica and beryl.
Do.	10	20·76	Mica, beryl and felspar.
Do.	1	1·26	Asbestos and kyanite.
Do.	4	9·32	Mica.
Do.	1	0·12	Graphite.
Do.	1	1·98	Muscovite.
Do.	1	0·54	Asbestos.
Do.	1	1·82	Mica, felspar and quartz.
Do.	1	3·2	Mica and felspar.
Beawar	5	30·46	Mica.
Do.	1	0·72	Asbestos.
Do.	1	0·6	Asbestos and soapstone.
Do.	1	1·84	Mica and beryl.
Do.	2	3·5	Mica, beryl and felspar.
TOTAL .	42		
MINING LEASES.			
Ajmer	1·	0·8	Mica, beryl and felspar.
Deolia Khurd Estate .	1	Whole estate	Mica.
Nagola Estate . . .	1	Do.	Do.
Nimod Estate . . .	1	Do.	Beryl.
TOTAL .	4		

TABLE 56.—*Prospecting License granted in Assam during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
Nongstoin State . .	1	640	Sillimanite, corundum and all associated refractory minerals.

TABLE 57.—*Mining Leases granted in Baluchistan during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
	MINING LEASES.		
Kalat	4	320	Coal.
TOTAL .	4		

TABLE 58.—*Prospecting Licenses and Mining Leases granted in Bihar during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Singhbhum . .	1	844·80	Chromite.
Do. . . .	1	725	Manganese.
TOTAL .	2		
	MINING LEASES.		
Hazaribagh . . .	7	411	Mica.
Santal Parganas . .	10	22·70	Coal.
TOTAL .	17		

TABLE 59.—*Prospecting Licenses granted in Bombay during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
		PROSPECTING LICENSES.	
Belgaum . . .	1	97·5	Manganese.
Kanara	2	2,227·15	Do.
TOTAL .	3		

TABLE 60.—*Prospecting Licenses, Mining and Quarry Leases granted in the Central Provinces during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
		PROSPECTING LICENSES.	
Balaghat . . .	42	2,958	Manganese.
Do.	1	134	Do.
Betul	12	6,604	Coal.
Do.	1	10	Limestone.
Do.	1	107	Red oxide of iron and ochre.
Bhandara . . .	42	2,900	Manganese.
Do.	1	179	China clay.
Do.	1	12	Red oxide of iron.
Bilaspur	1	581	Limestone.
Do.	1	186	Manganese.

TABLE 60.—*Prospecting Licenses, Mining and Quarry Leases granted in the Central Provinces during the year 1937*—contd.

District.	1937. No.	Area in acres.	Mineral.
	PROSPECTING LICENSES—*contd.*		
Chanda	3	1,545	Coal.
Do.	1	30	Clay.
Do.	1	28	Ochre.
Chhindwara	8	2,412	Coal.
Do.	3	227	Manganese.
Do.	1	146	Zeolites.
Jubbulpore	1	53	Antimony.
Do.	4	463	Bauxite.
Do.	2	71	Barytes.
Do.	2	465	Clay.
Do.	1	649	Coal.
Do.	3	480	Limestone.
Do.	1	26	Red oxide of iron.
Do.	1	61	Soapstone.
Do.	1	119	Felspar and clay.
Nagpur	21	2,776	Manganese.
Do.	3	739	Coal.
Raipur	1	2	Limestone.
Yeotmal	4	182	Do.
TOTAL	165		

TABLE 60.—*Prospecting Licenses, Mining and Quarry Leases granted in the Central Provinces during the year 1937*—concld.

District.	1937.		
	No.	Area in acres.	Mineral.
	MINING LEASES.		
Balaghat	6	567	Manganese.
Betul	2	656	Coal.
Bhandara	4	188	Manganese.
Chanda	1	22	Coal.
Chhindwara . . .	1	81	Do.
Jubbulpore . . .	1	25	Barytes.
Nagpur	3	222	Manganese.
TOTAL .	18		
	QUARRY LEASES.		
Bhandara . . .	2	69	Red oxide of iron and red and yellow ochre.
Do. . . .	1	64	White and china clay.
Bilaspur	3	14	Clay.
Chanda	1	22	Coal.
Drug	1	12	Limestone.
Jubbulpore . . .	3	57	Do.
Do. . . .	2	49	Soapstone.
Do. . . .	2	21	Clay.
Nagpur	3	63	Do.
Do.	1	8	Building stone.
Raipur	2	21	Clay.
Yeotmal . . .	4	47	Limestone.
TOTAL .	25		

TABLE 61.—*Prospecting Licenses and Mining Leases granted in the Madras Presidency during the year 1937.*

District.	1937. No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Anantapur	1	48·16	Steatite.
Do.	4	115·01	Barytes.
Do.	1	25·98	Asbestos, chromite and diamonds.
Bellary	3	1,164·88	Manganese.
Cuddapah	13	494·86	Barytes.
Do.	5	899·01	Asbestos.
Do.	2	643·50	Galena.
Do.	2	78·50	Iron-ore.
Do.	1	236·0	Lead, silver, antimony and zinc.
Do.	2	506·97	Lead, silver, copper, zinc and antimony.
Kurnool	5	83·76	Barytes.
Do.	1	5·00	Steatite.
Do.	2	1,006·20	Diamond.
Do.	1	63·44	Copper-ore.
Do.	1	200·20	Iron and copper pyrites.
Nellore	4	85·73	Mica.
Salem	1	520·74	Corundum.
Do.	1	64·36	Gold and silver.
Do.	2	54·32	Magnesite and chromite.
Do.	1	150·00	Magnesite, chromite, garnet and iron.
Tanjore	1	283·97	Black sand, ilmenite, monazite, zircon, rutile and garnet.
TOTAL	54		
	MINING LEASES.		
Cuddapah	2	325·50	Barytes.
Do.	1	18·0	Aluminium silicate.
Nellore	5	202·97	Mica.
TOTAL	8		

TABLE 62.—*Prospecting Licenses granted in the North-West Frontier Province during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Kohat	2	4,427	Natural petroleum.

TABLE 63.—*Mining Lease granted in Orissa during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
	MINING LEASE.		
Sambalpur . . .	1	71·49	Red oxide of iron.

TABLE 64.—*Prospecting Licenses and Mining Leases granted in the Punjab during the year 1937.*

District.	1937.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Attock	1	1,347	Coal.
Do.	2	14,800	Mineral oil.
Jhelum	16	2,714	Coal.
Do.	3	15,640	Petroleum.
TOTAL .	22		
	MINING LEASES.		
Jhelum	3	386·4	Coal.
Mianwali	2	2,994·86	Do.
TOTAL .	5		

MINERAL CONCESSIONS GRANTED IN BURMA DURING 1937.*

The number of concessions granted during the year was 317, of which 178 were new prospecting licences, 93 were renewals of previously granted prospecting licences and 46 were mining leases. The total number of concessions held on the 31st December 1937 was 597, of which 276 were held under mining leases and 321 under prospecting licenses. Details regarding the number of concessions classified according to the minerals for which they were granted are given below :—

(a) *Tin*—	
(1) Issued during 1937	24
(2) Held on the 31st December 1937	58
(b) *Oil-Shale*—	
(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	1
(c) *Antimony*—	
(1) Issued during 1937	7
(2) Held on the 31st December 1937	7
(d) *Iron-ore*—	
(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	10
(e) *Gold*—	
(1) Issued during 1937	2
(2) Held on the 31st December 1937	2
(f) *Gold and Platinum*—	
(1) Issued during 1937	5
(2) Held on the 31st December 1937	6
(g) *Gold, Silver and Platinum*—	
(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	1
(h) *Silver, Copper, Lead and Zinc*—	
(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	2
(i) *Coal*—	
(1) Issued during 1937	2
(2) Held on the 31st December 1937	2
(j) *Lead and Copper*—	
(1) Issued during 1937	1
(2) Held on the 31st December 1937	1

* Taken from "Report on the mineral production of Burma for the year 1937".

(k) *Silver and Lead*—

(1) Issued during 1937	2
(2) Held on the 31st December 1937	2

(l) *Antimony, Copper and Lead*—

(1) Issued during 1937	3
(2) Held on the 31st December 1937	3

(m) *Wolfram*—

(1) Issued during 1937	69
(2) Held on the 31st December 1937	81

(n) *Lead Oxide*—

(1) Issued during 1937	1
(2) Held on the 31st December 1937	1

(o) *Tin and Wolfram*—

(1) Issued during 1937	43
(2) Held on the 31st December 1937	100

(p) *Tin, Wolfram and allied minerals*—

(1) Issued during 1937	6
(2) Held on the 31st December 1937	21

(q) *Tin and allied minerals*—

(1) Issued during 1937	11
(2) Held on the 31st December 1937	35

(r) *Tin, Wolfram and Gold*—

(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	2

(s) *Tin, Wolfram, Lead, Gold and Silver*—

(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	1

(t) *Tin, Wolfram, Gold, Molybdenite and Bismuth*—

(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	1

(u) *Tin, Wolfram, Antimony, Lead and Silver*—

(1) Issued during 1937	1
(2) Held on the 31st December 1937	1

(v) *All minerals except Tin*—

(1) Issued during 1937	8
(2) Held on the 31st December 1937	9

(w) *All minerals except Oil*—

(1) Issued during 1937	64
(2) Held on the 31st December 1937	71

(x) *All minerals except Precious Stones*—

(1) Issued during 1937	2
(2) Held on the 31st December 1937	3

(y) *All minerals except Tin and Oil*—

(1) Issued during 1937	16
(2) Held on the 31st December 1937	20

(z) *All minerals except Oil, Tin and Wolfram*—

(1) Issued during 1937	1
(2) Held on the 31st December 1937	1

(aa) *All minerals except Tin and Wolfram*—

(1) Issued during 1937	2
(2) Held on the 31st December 1937	2

(bb) *All minerals except Tin, Oil and Precious Stones*—

(1) Issued during 1937	2
(2) Held on the 31st December 1937	2

(cc) *All minerals except Oil and Precious Stones*—

(1) Issued during 1937	3
(2) Held on the 31st December 1937	23

(dd) *All minerals except Gas and Precious Stones*—

(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	1

(ee) *All minerals except Oil, Precious Stones and Jade*—

(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	1

(ff) *Natural Petroleum (including natural gas)*—

(1) Issued during 1937	41
(2) Held on the 31st December 1937	121

(gg) *All minerals except natural Petroleum and natural Gas*—

(1) Issued during 1937	*Nil.*
(2) Held on the 31st December 1937	4

(hh) *Galena*—

(1) Issued during 1937	1
(2) Held on the 31st December 1937	1

THE WESTERN MARGIN OF THE EASTERN GHATS IN SOUTHERN JEYPORE. BY H. CROOKSHANK, B.A., B.A.I.(DUB.), *Superintending Geologist, Geological Survey of India.* (With Plates 20 to 24.)

CONTENTS.

I.—NATURE OF THE WESTERN MARGIN OF THE EASTERN GHATS.

Region mapped.

During the field seasons 1934-35 and 1935-36 I mapped a small part of the western border of the great charnockite mass, which, with the associated khondalites, forms the greater part of the hilly region known as the Eastern Ghats. The area mapped lies between the Jam river and Balimela (18° 15′ : 82° 7′). This is a stretch of some 30 miles, only a tenth part of the length of the range, but, judging from the descriptions of other portions by Dr. T. L. Walker (1900, pp. 166-176, 1902, pp. 1-21) and Mr. C. S. Middlemiss (1902, pp. 21-23, 1903, pp. 23-25) it is quite typical.

Reasons for mapping.

Sir L. L. Fermor desired me to visit this region partly because the natural border of the great crystalline area of Bastar and Jeypore, which I am engaged in mapping, lies there, and partly because he was very anxious

to ascertain whether the western margin of the Eastern Ghats was here a fault. The belief that such was the case was very generally held. It had originated by a tentative suggestion of Walker (1902, p. 10). Middlemiss did not subscribe to this belief in his published work, but he made suggestions similar to Walker's in his unpublished progress report for 1902-03. The strongest evidence of a faulted boundary seems, however, to be the regular linear boundary between the crystallines and the charnockites shown on the 1 inch to 32 miles geological map of India.

Such a fault, if the upthrow were to the east, might have raised the Eastern Ghats some thousands of feet, and an uplift of this nature would, according to Fermor (1935, p. 48), account for the relatively high grade of metamorphism met with in some of the rocks of this region.

Views of earlier observers.

In discussing the nature of the margin of the Eastern Ghats the views of earlier observers must be considered. Walker and Middlemiss are the only geologists who had visited this region before me. Of these two Walker's views are the more important because he mapped a large part of the boundary region. Middlemiss mapped for the most part further to the east and only made a few traverses as far west as the boundary.

Walker's evidence.

In 1899 Walker mapped most of central Jeypore including the area immediately north of my map. In his published description of this area (1910, p. 171) he makes the following remarks about the charnockites and their boundary with the crystalline schists lying further to the west.

'I am inclined to regard these hypersthene rocks' (*i.e.*, the charnockites) 'as forming a great igneous stock, though it would be very difficult to prove conclusively that this was the case'. Again he reports 'numerous small hills of the same lithological character as the large massif, not indicated in the accompanying geologically coloured map, lie like islands in the schist complex'.

The following is his description of the boundary :—

'The actual contact with the crystalline schist is nowhere exposed and the boundaries of the islands as well as the main *massif* as marked on the geological map, are only approximate at best'. His map, however, showed that he thought the boundary an irregular one.

Later, in discussing the geology of the Kalahandi State, Walker (1902, p. 10) qualified his earlier formed opinion that the boundary of the charnockite ellipse was an intrusive one by the following statement :—

'For some reason as yet unexplained sillimanite-schists do not occur along the western margin in the vicinity of Jeypore'. 'There are, however, evidences indicating a faulted western boundary for the charnockite ellipse, in which case the upthrow of the schists would expose them to denudation, which may account for their absence along the western side of the massif'.

This statement shows that Walker visualized a former covering of sillimanite-schists, or khondalites as he christens them on the following page, over the gneissic plains of Jeypore. This cap of khondalite has according to him now disappeared because it was raised by a fault above the level of the khondalites covering the charnockites further east and has since been totally removed by denudation. The point to be noted is that he considered that the upthrow was on the western side of the fault.

It is not certain what Walker's 'evidences' of faulting were. He mentions in both of his publications that the most marked direction of strike in the older gneisses is north-west compared with north-east in the charnockite ellipse but that north-easterly slickensiding is also widespread in the older gneisses. He explains the north-westerly strike of the older gneiss as being the imprint of some pre-charnockite earth movement. The slickensiding he considers is evidence that the older gneisses were subjected to the same stresses which gave the charnockite its existing strike. Fermor (1936, p. 143) considers that this slickensiding 'adumbrates' the presence of a fault at the western margin of the Eastern Ghats. He may be right but I cannot follow his argument myself. My own view is that Walker's 'evidences' of faulting were (1) the sudden change in geology on either side of the charnockite margin and (2) a desire for a fault which would explain the absence of khondalite over the plains of central Jeypore.

Middlemiss' evidence.

Middlemiss has expressed no opinion about the western margin of the charnockite in his published reports but in an unpublished progress report he makes the following statement :

'As far as one can deduce from an obscure junction veiled by steep hilly rock-strewn slopes in conjunction with an alluvium

covered plateau, the line of demarcation between the two bands (*i.e.*, charnockite and gneiss) is sharp and decisive, though whether it can be spoken of as a fault or fold-fault accompanying the hilly mass of band II to the south-east is problematical '.

He also mentions ' a little charnockite in the gneissic complex '.

I have recently examined Middlemiss' maps, specimens, slides, and diaries, and though I could not find many of the villages mentioned by him on the topographical maps, I was fairly successful in following his movements. From these it was clear that he was mapping very rapidly and that he made no attempt to follow the boundary between the charnockites and the gneissic complex. He did however make a number of traverses across the boundary at rather wide intervals. His evidence is, therefore, an expression of opinion based on a few traverses at rather wide intervals, an opinion moreover which he did not wish to publish.

The boundary drawn by him is almost a straight line. It closely follows the edge of the plain and joins up with Walker's boundary further to the north. There is no indication on the map that he thought the boundary a fault.

Results of recent mapping.

The recent mapping of the boundary between Balimela and the Garia river, where Walker's map begins, shows that the edge of the charnockite massif is not a straight line nor does it follow the edge of the plain, as sketched by Middlemiss. On the contrary it is very irregular (see map). I am satisfied that I had a better chance of achieving accuracy than the older observers, for I had the benefit of excellent new topographical maps, and I was able to check my field results by microscope work on the ground. I was also making a deliberate attempt to plot in the boundary, whereas the older observers were making a reconnaissance of the whole area. The type of boundary shown by me agrees well with that shown by Walker further to the north. Examination of his specimens shews that his map was the result of following the boundary for some distance, and is not based like Middlemiss' map on mere traverses.

As regards the change in strike between the charnockites and the older gneisses noted by Walker, I have not observed any sudden change. A reference to my map shows that the strike in the older gneisses is somewhat variable. In the majority of cases it seems to be east-north-east like that of the Eastern Ghats. Sometimes

it seems to have been affected by minor charnockite intrusions and runs parallel to their margins. Often it seems to be quite irregular. There is, however, no sudden and marked change along the margin of the main charnockite mass.

Walker's slickensides, which Fermor quotes as evidence of a faulted boundary for the charnockite ellipse, were not noted by me. It is, I think, quite possible that they escaped my observation.

Intrusive nature of the charnockites.

The normal explanation of a boundary like Walker's or mine is that it is an intrusive one. This view is greatly strengthened by the discovery by all three observers of numerous minor charnockite intrusions in the older gneisses lying to the west of the main massif.

Contacts between the rocks of the charnockite series and the older gneisses have not been described either by Walker or by Middlemiss. This is largely due to the debris and thick forest growth along the base of the main range. I have recorded one good junction between a large intrusion of hypersthene-granite-gneiss and a porphyritic biotite-gneiss in the glen south of Pusapalle (18° 18′ : 82° 2′).

At the main junction the dividing line between the two rocks is almost vertical, and quite distinct. The gneiss at the contact looks somewhat indurated. The charnockite is abnormally micaceous, but could be matched by micaceous specimens from the interior of the same charnockite mass.

Along the same stream there is a swarm of minor charnockite intrusions in the biotite-gneiss. Here the junction between the two rocks is much less clear, and the one has possibly assimilated the other to some extent.

Microscopic examination of the rocks from either side of the main junction showed that they were both much albitized. This has led to a secondary development in both rocks of biotite, hornblende, albite, quartz, iron-ore, and apatite at the expense of potash felspar and the earlier formed ferro-magnesians. This process, if continued, would have ultimately reduced both rocks to biotite-hornblende-granulites almost indistinguishable from one another. As albitization is probably greatest along a junction, it is perhaps to this process, as much as to the prevalence of jungle and debris, that the scarcity of good contacts is to be ascribed.

It would be unfair to use the evidence obtained at one contact as proof that the junction is intrusive, but it is safe to say that

there is nothing in the appearance of this contact to disprove the opinion already put forward that the junction is a normal intrusive one.

Large masses of hypersthene-granite along the charnockite margin.

The irregular margin of the main charnockite mass is largely due to the existence of numerous large masses of hypersthene-granite-gneiss which jut out irregularly into the older gneisses lying further to the west. These would in my opinion suffice to prove that the contact was intrusive were the charnockite normally of the same composition as its offshoots. This is not so. The main mass of the charnockite is a patchwork of igneous intrusions grading from acid to ultra-basic. All these agree in containing hypersthene and so are related, but some of them have been intruded later than others. In particular the acid intrusions of the western margin of the *massif* are younger than the main mass.

Possible pre-charnockite faulting.

It is now impossible to say what was the nature of the contact between the main body of the charnockites and the gniesses of the Jeypore-Bastar region before the intrusion of the acid charnockite along this junction, but it is not improbable that it was a thrust-plane or even a boundary fault, though no evidence of such a dislocation can be seen at the present time.

Fermor's views opposed to those of all field observers.

Be this as it may, Fermor makes a mistake in quoting Walker as evidence of a great fault with upthrow to the east. Actually Walker claims that the fault, if any, had an upthrow to the west (see p. 3). Nor does Fermor seem on very safe grounds in claiming that the uplift of the Eastern Ghats as the result of this fault has brought to the surface rocks metamorphosed in the katazone.

As the following excerpts from Middlemiss, Walker and F. H. Smith show, none of the field workers in the charnockite-khondalite region have taken this view.

Middlemiss (1903, p. 24) says 'The khondalites are regarded as originally sedimentary rocks now completely metamorphosed by the intrusions of charnockite and granite'.

Walker (1902, p. 10) remarks 'The composition of the sillimanite schist' (later called khondalite) 'taken along with the nature of the rocks with which it is associated compels one to regard this group as para-schists, while their occurring above the charnockites, granitoid gneiss, and other coarse gneisses, all of which appear to

be igneous in origin, suggests that we are dealing with rocks formed by the metamorphism of ancient sediments, very probably by the intrusion of the great igneous masses referred to, and by the action of a mountain building force acting in a line at right angles to the north-north-eastern foliation frequently observed in the rocks of the Kalahandi State'.

Smith (1900, p. 154) takes a somewhat different view. He states :—'The schist evidently represents a more or less metamorphosed series of ancient sedimentary rocks, originally consisting of ferruginous shaly sands and grits with bands of impure limestone. In places the schist passes gradually into these sandy and gritty forms, but usually the latter has been entirely altered chiefly by dynamo-metamorphism, into true crystalline rocks, of which the commonest form is a quartz-garnet schist always rich in sillimanite' (*i.e.*, a khondalite).

While I have not seen enough of the khondalite-charnockite junction to be confident of its nature I tend to be in complete agreement with the views of Middlemiss and Walker.

The uplift theory, if correct, would explain the difference between the high grade metamorphism of the khondalites and the rather low grade found in the sedimentaries of Bastar between latitude 18° 22′ and latitude 19°. Recent mapping has shown that further south in Bastar the paragneisses are characterized by the same sillimanite considered to be the hall-mark of high grade metamorphism in the khondalites. Either the supposed faulting is not the cause of the change in metamorphism, or else the fault must die out south of this latitude.

II.—THE OLDER GNEISSES IN THE MALAKANAGIRI TAHSIL.

Introduction.

The presence of a great boundary fault along the western margin of the Eastern Ghats was assumed by Sir L. L. Fermor (1935, p. 48) to be the explanation of the sudden change in the grade of the metamorphism there. Now that it has been shown that there is no real evidence in support of such a fault, and that, if one in fact exists, it is most probably a dislocation which took place before the end of the charnockite period, some other explanation of the supposed sudden change in metamorphism at the margin of the Eastern Ghats is required.

In order to discuss this a clear idea of the rocks in the border zone is necessary. The following pages are, therefore, devoted to a description of these.

I propose to make this description brief where the ancient gneisses and schists are concerned, as these belong to the Bastar-Jeypore rather than the charnockite province. They cannot be entirely neglected, as the grade of metamorphism shown by them must be compared with that observed in the main charnockite massif, and also with that found in the outlying intrusions of hypersthene-granite-gneiss so common in the border zone.

I give a somewhat more complete description of the charnockites, but here again no detail is given where such rocks have already been described by Sir T. H. Holland (1900) and others.

Biotite-gneiss.

The commonest rock to the west of the charnockite *massif* is a very fine-grained biotite-gneiss. Typically (23197) this is made up of fine angular grains of quartz and felspar with a small but variable quantity of green biotite. The commonest felspar is microcline in small angular grains lying in all directions. These grains are often crowded together, and seem to be the broken remains of larger crystals. Orthoclase also is almost always present. In some slides (23265, 23266, 23190, 23252) the potash felspars occur in large crystals surrounded by finer-grained material, and show excellent mortar structure. They are normally free from the microperthitic textures so characteristic of the potash felspars in charnockite.

Albite and oligoclase are always present. The former is frequently difficult to distinguish from quartz owing to the similarity of their birefringence, and the absence of twinning. Myrmekite optically continuous with the albite is often seen developing at the expense of the potash felspar, but the phenomena of this kind are not nearly so striking as those to be described in the sequel, in connection with the minor charnockite intrusions (see pp. 24-25).

Quartz, though always present, forms quite a small part of the rock compared with the felspars.

The biotite is a dark green variety quite distinct from the brown biotite seen in the aluminous schists further west in Bastar State. The crystals are usually arranged in irregular lines or streaks, but individual crystals are rarely oriented parallel to these lines. In some slides (23199, 23213) the biotite is arranged in felted masses around crystals of sphene which in turn encircle grains of iron-ore.

In such cases it is probably a secondary growth similar to the albite which develops at the expense of the potash felspar.

Hornblende is often present (23189, 23190). It has a pleochroism from pale greenish yellow to greenish blue and an extinction angle of about 24°. It is probably a soda-rich variety.

Iron-ore, epidote, zoisite, and sphene occur in many slides. The sphene is in many cases a corona around iron-ore, and the epidote round zoisite. All these minerals are commonly associated with the biotite and are partly due to its alteration. In some cases the biotite is much altered to chlorite.

Muscovite is rather rare, but sericite is a common inclusion in the albite. Epidote and quartz occur included in this way also.

Garnet is rare, but is found in biotite-schists from the edge of the charnockite (23192, 23195). It does not appear to be due to any very high grade of metamorphism, for epidote, sphene, and green hornblende are associated with it. In slide 23213 the garnet seems to be developing from a felted mass of biotite.

Apatite is the commonest accessory. Zircon is also frequently seen.

On comparing the localities from which my specimens were collected with the slides, I find that the number of large potash felspars decreases gradually as the charnockite range is approached. With the disappearance of the large crystals, mortar structures are also lost. Nevertheless I consider the fine-grained biotite-gneisses of the charnockite margin to be granulated forms of the slightly porphyritic ones further west, and that these in their turn grade into the porphyritic gneisses lying just to the east of the Jeypore-Bastar border. All are probably metamorphosed porphyritic granites. The garnet which sometimes appears in the biotite-gneiss near the edge of the charnockite may be a contact effect, or may be due to increasing stress.

Hornblende-schists.

Associated with the biotite-gneisses are numerous hornblende-schists (23212, 23188, 23194). These are essentially composed of felspar and hornblende with abundant inclusions of quartz. The hornblende is similar to that which occurs in the biotite-gneiss. Albite, oligoclase, and labradorite are the usual felspars. These often show strain phenomena. Biotite, iron-ore, sphene, epidote, and zoisite are all very common. The last mentioned pair occur in most cases as small idiomorphic crystals included in all the varieties of felspar. Garnet

is present in many of the hornblende-schists (23188). It is rather sporadic in its occurrence, but becomes distinctly commoner as the main charnockite range is approached.

I consider the hornblende-schists to be metamorphosed igneous rocks. The prevalence of labradorite in them certainly supports this view.

Dr. T. L. Walker (1900, p. 168) considered both the biotite-gneisses and the hornblende-schists north of Govindpalle to be para-gneisses. He based his opinion on the relative abundance of quartz in them as compared with felspar. Examination of his slides, which were made in 1899, shows that they were too thick to distinguish between quartz and felspar, unless the latter was well twinned. As the rocks contain a large quantity of untwinned albite, he must have overestimated the quartz at the expense of the felspar. It is possible, however, that he is right and I am wrong. The point is not of great importance as the chief interest of these rocks lies in their grade of metamorphism.

Quartzites.

Large masses of white crystalline quartzite occur in many places among the hornblende-schists and biotite-gneisses. It is uncertain whether these are quartz veins or acid pegmatites.

On the margin of the charnockite near Gumiribadaguda (18° 28′ :82° 15′) is an occurrence of magnetite-garnet-grünerite-quartzite.

Potstones.

Coarse potstones composed mainly of chlorite with a little iron-ore are common along the charnockite border. They are probably metamorphosed ultrabasic rocks.

THE METAMORPHISM OF THE OLDER GNEISSES.

The characteristic minerals of the older gneisses and schists to the west of the Eastern Ghats are biotite, green hornblende, chlorite, albite, zoisite, epidote, sphene, and, in the vicinity of the main charnockite mass, garnet. Mortar structures, strain polarization, bending of crystals, and other indications of mechanical stress are all very common, though some rocks show them better than others. All these minerals are commonly found in rocks of low to medium grade metamorphism. Minerals associated with rocks of higher metamorphic grades are not normally found in this area.

I conclude from the general mineral suite that the grade of metamorphism west of the Eastern Ghats is low to medium. The

absence of remains of minerals characteristic of the higher grades of metamorphism indicates that the mineral suite found throughout this area is not the result of retrograde metamorphism. The evidence of widespread mechanical stress among these rocks strongly favours my conclusions.

III.—THE NEWER DOLERITES.

The newer dolerites occur locally as dykes and small intrusions in the gneisses to the west of the Eastern Ghats, and also in the charnockites of the main range. In hand specimens they are black rocks hardly distinguishable from the epidiorites so common in Bastar State.

Under the microscope they are seen to be composed of augite, labradorite, and iron-ore with a little mesostasis of quartz and undetermined felspar. In the less altered rocks such as 23222, the only trace of metamorphism is a greenish rim around the edge of the augite. In more altered varieties (23187, 23202) (Pl. 22, fig. 3) garnet generally displaces the green chlorite. In some cases the development of garnet has been so remarkable that only cores of augite and a mere fraction of the original felspar survive. Even in such cases the ophitic texture is not completely destroyed. Strangely enough the original constituents of the dolerite are often seen altered to garnet at one part of a slide, and to chlorite at another. Garnet, and less commonly biotite, form coronas round many of the original grains of iron-ore. Apatite in fibrous crystals is the only other mineral present.

The mesostasis of the dolerite is distinctly seen in many slides (23206). It is composed of an intergrowth of quartz and felspar, the former greatly predominating. These intergrowths differ strikingly from the myrmekite so commonly seen in the acid charnockites. In the first place they are definitely interstitial with respect to the older felspars, and never seem to have corroded them as the myrmekite has. Also their texture is graphic, the two minerals being separated sharply by straight lines, whereas in the myrmekite the quartz always occurs as vermicular streaks and rounded blebs. Finally quartz preponderates in the mesostasis of the dolerite, but is present in relatively small amounts in the myrmekite.

I am stressing the difference in the two types of intergrowth, as in the sequel I have attempted to fix the age of the myrmekite on the assumption that it does not occur in the newer dolerites.

Age.

The age of the newer dolerite is clearly younger than that of the charnockite, as dykes of it cut the charnockite in several places. It has never been found intruded into the Cuddapahs, though it has been found in the rocks surrounding the Sukma Cuddapah basin. In all probability it is older than the Cuddapah system.

Metamorphism.

The metamorphism of the newer dolerites is of considerable interest. They contain no epidote, zoisite, or sphene, although the epidiorite intrusions in the older gneisses are crowded with these minerals. It is clear therefore that they have escaped the earlier metamorphism which converted the older dykes to epidiorites. On the other hand they show a quite remarkable development of garnet, and in a few cases (23231, 23232, 50/123) mortar structure, bent felspars, and other signs of stress. The garnet cannot, however, be correlated with the stress, because in some slides (23231) where there are marked signs of stress there is no development of garnet. The garnet does seem to be most common in rocks from the charnockite range and its immediate vicinity, but there are so many exceptions that it would be unsafe to draw any conclusions from this circumstance. In the slides where the augite has a narrow rim of chlorite and there is no other marked change, petrologists would agree that the metamorphism was low grade. When portions of a slide show rims of garnet and other parts rims of chlorite, the problem becomes a little more difficult. But I think that if chlorite rims be accepted as a sign of low grade metamorphism in one rock, they must be accepted as such in all rocks of the same kind; and if the chlorite rims are due to low grade metamorphism, then the garnet rims which occur along with them must be so also.

Exception to this view has been taken on the grounds that the garnet is the high-water mark of metamorphism in these rocks, while the chlorite is a later development due to retrograde metamorphism. This is a possibility, but an unlikely one, as the garnet is usually quite fresh and does not appear to be altering to chlorite.

Holland (1896, pp. 20-30) has described a similar development of garnet in rocks from Madras and Bihar. There are, however, important points of difference between Holland's rocks and the Malakanagiri dolerites.

In the former, garnet develops directly from pyroxenes with deposition of felspar as a by-product. In the latter, the garnet is the product of interaction between the labradorite and the augite of a dolerite.

IV.—THE CHARNOCKITE SERIES IN THE EASTERN GHATS.

No attempt was made to map accurately the different types of charnockite in the main range, as this was outside the scope of my work. Several traverses into and across the hills were, however, undertaken. As a result, it is known that the commonest rock in the heart of the range is a charnockite of intermediate composition. Basic, ultrabasic, and acid types tend to be concentrated along the western edge of the main mass.

The chief difference between the charnockites of this area and those described by Holland, Walker, F. H. Smith and others is that these rocks have in most cases been crushed. They therefore show all sorts of strain phenomena extremely well.

Crush phenomena.

Slide 23203 from near Bodapalle (18° 28′ : 82° 19′) is typical of the intermediate charnockites in the main range, except that it is rather too basic.

It will be seen (Pl. 20, fig. 1) that the hypersthene is arranged in linear streaks. It has been granulated, and altered to green chlorite and iron-ore both at the margin and along numerous cracks. A pale green pyroxene is also present, crystals of which generally show contorted cleavages.

Felspar (about andesine) is very abundant, and is cracked, strained, and granulated in the same way as is the hypersthene (Pl. 20, fig. 2). Albite is fairly common, but there is no quartz nor recognizable potash felspar.

Slide 23201 from the same locality is much more acid. It contains only a few streaks of hypersthene, but microperthite and quartz are relatively abundant. It shows all the cataclastic features of 23203. In the field it would be impossible to draw a boundary between these two rocks.

The cataclastic phenomena reach their maximum in the south of the area mapped. Here the rocks are rather more acid than usual. Pl. 20, fig. 3 illustrates a somewhat more advanced stage of cataclasis, in which the hypersthene is drawn out into elongated streamers, and the quartz and felspar occur in flattened bands.

Idiomorphic masses of garnet in association with iron-ore are often present at this stage (23226).

Further crushing leads to almost complete destruction of hypersthene, and an increased development of garnet and iron-ore. Granular hornblende is also abundant. The ultimate stage is a finely granular rock (23241, 23243) consisting of bands of quartz, hornblende, garnet, and iron-ore. Felspar may also be present, but it cannot be distinguished owing to the absence of twinning and the fineness of the grain.

In the more basic charnockites the pyroxenes and felspars are drawn out into parallel streaks at an early stage (23225). Later the pyroxene breaks up into hornblende, garnet, and iron-ore. Granulation is intense, and the final result is a banded rock resembling the crushed granitic charnockites, except that hornblende, garnet, and iron-ore are more abundant, while quartz is scarcer (Pl. 20, fig. 4). In all the slides which I examined there were residual crystals of pyroxene which had survived the granulation.

In many areas (see map) finely banded rocks composed of iron-ore, quartz, and garnet with a little hypersthene and pyroxene were found. These are believed to be due to the crushing of the more basic types of charnockite. In some cases they are sufficiently rich in iron to be used as ores, and are quarried to a small extent by the local iron-makers.

Uncrushed charnockites.

It is a remarkable fact that though most of the charnockite in the main range shows signs of crushing, there are numerous masses, both acid and basic, along the outer border of the range, which appear in the hand specimen to be uncrushed. Microscopic examination of these generally shows mortar structures, distorted twins, and similar phenomena, but some of the more basic ones show no more metamorphism than the rocks of similar composition described by Sir T. H. Holland (1900, pp. 133-170) in Madras. The phenomenon is all the more striking because the main mass in contact with these lesser intrusions is frequently intensely crushed. It is surmised that the uncrushed masses have been driven into their present position at the close of the charnockite period of igneous activity, and that the stress which ground up the earlier intrusions had waned before they were consolidated.

Garnet is locally abundant in the main charnockite mass, but it is by no means universally present. It is commonest where the

Garnet in the charnockites.

granulation is greatest, and is therefore correlated more with stress than with high temperature. This mineral is a marked feature of the hybrid gneisses in Bastar State. No evidence of its hybrid origin is here available; nevertheless it is quite likely that assimilation of older rocks by the charnockite magma has brought about conditions favourable to its development. A local increase in temperature where crushing has been greatest has probably also favoured its growth.

METAMORPHISM OF THE CHARNOCKITES IN THE MAIN RANGE.

The metamorphism of the main charnockite mass is characterized by the abundance of stress phenomena and by the presence of garnet. It has probably been brought about at quite a moderate temperature, but with the maximum stress possible at that temperature.

Admittedly some geologists (Stillwell, 1918, pp. 190-192) have claimed that the stress phenomena are only evidence of a second stage of metamorphism imposed on rocks which had already been subjected to a high grade of metamorphism, and they would quote the presence of hypersthene as evidence of this earlier high grade stage.

Hypersthene does frequently occur in high grade metamorphic rocks, and so this view cannot lightly be dismissed, but I propose to show that among the small intrusions of charnockite, which are a common feature among the older gneisses to the west of the main range (see map), hypersthene is an original pyromorphic mineral (pp. 423-425). It is difficult to believe that the hypersthene in the charnockite of the main range could have a different origin from that which occurs in its minor apophyses.

V.—CHARNOCKITE INTRUSIONS IN MALAKANAGIRI.

Norites.

Numerous small bosses of a rock closely resembling charnockite are intruded into the older gneisses all along the margin of the Eastern Ghats. Most of these lie within ten miles of the main range, but a few have been found even further afield. Basic, intermediate, and acid types are all present, but basic ones are relatively rare. They were seen, however, on hills south of Champakari (18° 22′ : 81° 56′) and Dongorokolli (18° 31′ : 82° 6′), and in the Putparvatam and Guppakonda

reserved forests. In appearance and mineralogy they resemble the norites described by Holland 1900, pp. 133-170 in Madras.

They rarely show any signs of the crushing so commonly seen in the more acid rocks in this region. In most cases (24,426, and 24,431) the rocks are quite unaltered, but sometimes (24,434) the hypersthene has coronas of green biotite, and the pyroxenes tend to be altered to hornblende (23,289). In a specimen of this kind, albitization was also noted. The albite occurred on the outside edge of a biotite corona, and seemed to be replacing andesine, but as there was no development of myrmekite it was impossible to be sure of this.

INTERMEDIATE AND ACID HYPERSTHENE-GNEISSES.

The largest and most important occurrence of these rocks lies in the region between Malakanagiri and Balimela. Here a number of hills of a dark-coloured granitoid rock rise abruptly from the surrounding plains. In hand specimens this rock is coarse-grained, dark green or grey in colour, with porphyritic crystals of felspar $\frac{3}{4}$ inch long by $\frac{1}{4}$ inch wide, and fine interstitial material in which crystals of quartz can just be distinguished. No ferromagnesian minerals can be recognised with the naked eye.

Under the microscope the porphyritic features of the rock are less conspicuous than in the hand specimen. The great size of the porphyritic crystals is very readily seen, but their rhombic shape is generally disguised by the corrosion of their faces. It is clear enough, however, that the original margins of the porphyritic crystals were in many cases rectilinear.

This rock varies in mineral composition between wide limits, but speaking generally it is a mosaic of quartz and felspar with minor quantities of ferromagnesian minerals, none of which show distinct crystal faces. Mortar structures, cracked crystals, bent felspar twins, and brush polarization are all rather common, and show conclusively that the rock has been somewhat crushed. As the result of this crushing, and probably also due to subsequent albitization of the felspars, many of the specimens examined show marked granulitic features. As these igneous rocks are crushed and somewhat metamorposed, and because it is a convenient term, I propose to refer to them in the sequel as hypersthene-gneisses. I wish to make it clear, however, that they are not streaky nor banded as is the case with so many of the Indian gneisses.

Ferromagnesian minerals in the hypersthene-gneisses.

Ferromagnesian minerals make up a variable but usually small part of these rocks. Foremost among them, and almost always present, is hypersthene. It occurs in small rounded or elongated grains, and never shows distinct crystal faces. Its extinction is straight, or nearly so, and its pleochroism is from pale pink to pale green, a well-known characteristic of hypersthene in the charnockite series.

Rather large irregular masses of pale green pyroxene are also common. About Malakanagiri this mineral occurs along with hypersthene, but in the the crushed rocks of similar composition along the margin of the charnockite range it is sometimes the only pyroxene present.

Other femic minerals present are hornblende, biotite, and chlorite. The hornblende (24,448, 24,425, 24.430) is due to the alteration of pyroxene in most cases. It is then an olive-green variety. There are also a few grains of blue hornblende which are believed to be due to reactions between some of the ferromagnesian minerals and the soda solutions that have invaded the rock in many areas after its consolidation (*see* pp. 426-429).

In the fresher hypersthene gneisses (23,196, Pl. 21, fig. 1) there has been little reaction at the margin of the hypersthene. At most there is a faint greenish rim, probably due to the incipient development of biotite or chlorite. More altered varieties show much more striking phenomena. An example of this kind from the western face of Munas (18° 20′ : 82° 57′) contains rather a lot of hypersthene (24,425). This is all highly altered and has a dark ferruginous border outside which is a narrow zone consisting of minute flakes of hornblende or biotite in a matrix of quartz, possibly with some albite. This passes outwards into a comb of greenish yellow biotite which extends irregular fingers (Pl. 22, fig. 2) into the surrounding perthite and albite-oligoclase. In some cases these fingers put off irregular shoots along the cleavage directions of the felspar (Pl. 22, fig. 1).

In slide 24,430 from hill 1,449 north-east of Munusakonda (18° 21′ : 81° 58′) the hypersthene is even more decomposed, and is largely replaced by granules of iron-ore. It can, however, just be recognized by its straight extinction and typical pleochroism.

The reaction phenomena in this slide are very varied. In one case there is a central core of cryptocrystalline material representing

the original hypersthene. Round this is a finely granular zone mainly composed of green and blue hornblende from which fingers of hornblende stretch out into the surrounding albite aureole. This in its turn seems to be eating its way into a large potash felspar.

Beautiful developments of myrmekite (Pl. 21, fig. 4) are nearly always associated with biotite, and in one case biotite has actually replaced the albite of a myrmekite. Where biotite occurs as a corona round hypersthene, and is itself surrounded by a corona of albite, the albite seems to have developed direct from a potash felspar without intermediate myrmekite.

Felted masses of biotite, hornblende, iron-ore and apatite often occur along irregular cracks (24,447) in the felspars, and do not seem to have replaced earlier ferromagnesians. In such cases biotite certainly developed directly at the expense of earlier formed felspars.

The biotite and hornblende do not appear to be original constituents of the rock. They are closely associated with the albite which has replaced so much of the potash felspar, and are probably the same age as it. There is little doubt that all these minerals are the results of reactions between late magmatic waters and the original minerals of the rock.

The salic minerals in the hypersthene-gneisses.

A great part of the Malakanagiri hypersthene-gneiss is made up of large crystals of perthite retaining traces of their proper crystal form in spite of the corrosion of their margins. In some slides (23,230 B) a little microcline is present, but on the whole it is rare. Both the perthite and the microcline show the microperthitic structures described by Holland 1900, p. 140 in his charnockite memoir.

Corroding the perthite and in some cases completely replacing it, are numerous masses of albite, oligoclase, and quartz. Although some of these minerals have clearly developed at the expense of earlier potash felspars, some were probably also original constituents of the rock. There is, however, no means of distinguishing original from secondary where all display irregular boundaries.

Rocks from different areas vary greatly in the relative proportions of soda and potash felspar, but in typical specimens they seem to be present in about equal amount.

Quartz occurs in all these rocks, in rather large patches with rounded boundaries but of no particular shape. There is a tendency for it to be concentrated in irregular bands associated with patches of albite. In appearance it is water-clear and fresh. It shows

under crossed nicols a brush polarization similar to that seen in vein quartz. It also occurs as minute rounded granules along the edges of the larger crystals in rocks where mortar structure is well developed, and as small vermicular masses in myrmekite.

The larger patches of quartz are full of minute inclusions. The commonest of these resemble tiny bubbles, and are arranged about cracks in the mineral. I cannot say whether they really are bubbles or not. In some slides thin black bars are arranged along the crystallographic directions of the quartz just as Holland (1900, pp. 135-140) describes in the Madras charnockite. In other slides of similar rocks no bars were seen.

How far the quartz is an original constituent of these rocks is uncertain, but many of the larger pieces have been cracked like the potash felspar, and are probably the same age as it.

Felspars grading from albite to andesine are extremely abundant. They can readily be distinguished from the potash felspars, as their refractive index is always greater than that of Canada balsam, but they are not so easy to separate from quartz, as they have a similar birefringence, and are often not twinned.

In a great many cases albite can be seen in process of development from a potash felspar with myrmekite as an intermediate stage. This peculiar intergrowth of quartz and albite develops like a wart on the surface of the albite and extends deep into the substance of the perthite (Pl. 22, fig. 1). It is usually in optical continuity with the albite with which it merges insensibly. Its junction with the potash felspar is very different. The line of junction here is distinct. From the junction itself starts a host of minute streams of quartz flowing towards the core of the wart. On their way these streams run together, and form vermincular masses and blebs. Judging from the birefringence and refraction of these blebs they are undoubtedly composed of quartz. The matrix in which they develop is almost always albite, but instances where they have grown in oligoclase are known (24,428).

In cases where the plane of the micro-section has chopped off the head of such a wart, an inclusion of myrmekite showing a very beautiful network of fine quartz veins is seen in the middle of a perthite crystal. In one section of this kind the inclusion was in optical continuity with an adjacent albite, from which a second wart of myrmekite was protruding into the same perthite crystal. Although the most conspicuous myrmekite growths are like warts, it is

common to see a linear development of myrmekite between crystals of albite and potash felspar. In such cases the corrosion of the myrmekite is never deep.

The blebs of quartz which develop in the myrmekite always disappear before they reach the main albite crystal, for that mineral never contains many quartz inclusions. Probably most of the myrmekitic quartz finds its way into the fine granular aggregate which separates the larger felspar crystals.

In many cases albite developing from potash felspar is cloudy. This cloudiness seems to be due to an intergrowth of fine flakes of sericite with the albite (23,230 B).

All the felspars in the Malakanagiri gneisses are cracked, whether they be early formed ones like the potash felspars, or late developments like the soda ones. It is noteworthy that the system of cracks in the perthite is severed and obliterated where myrmekite warts have crossed it, and that the albite developing from the myrmekite has developed a different system of cracks. This indicates, I think, that the rock was continuously under stress from the time when it was consolidated till the albitization ceased.

Oligoclase is always present as well as albite. It can be distinguished from that mineral by its good twinning, and relatively high refraction. In some cases this is distinctly higher than quartz. Its birefringence is also notably lower than that of albite. In cases where it has been possible to observe the extinction angle of the oligoclase it has been about 10°.

As with albite some of the oligoclase has developed at the expense of potash felspar with myrmekite as an intermediate stage (24,428). As this is relatively rare it is probable that most of the oligoclase is an original constitutent of the rock.

Iron-ore.

Iron-ore occurs as large irregular masses with rounded boundaries. It is usually associated with the femic minerals which it replaces locally, and from which it is doubtless partly derived. It also occurs alone or with biotite along cracks and between the crystals of other minerals (24,447). Here it has most probably been deposited from solution.

Apatite.

Associated with the iron-ore and biotite, and also to a small extent disseminated throughout the rock, occur numerous large rounded grains of apatite. In places it is so common that it seems to be an intergrowth with the iron-ore. In some specimens minute

idiomorphic apatite crystals are included in the felspars. These seem to be quite distinct from the rounded ones, and have probably been formed during the consolidation of the original magma.

Zircon. Zircon is present in all the hypersthene-gneisses but is much less common than apatite. Sometimes it occurs as very large crystals among the ferromagnesian minerals.

Nomenclature. As already stated, the amount of each minerals present in the rock varies much from place to place. The variation is, however, continuous, so that it is never possible to draw a boundary between the more basic and acid types. The rock analysed (24,448) (49/571) may be taken as representative of the most basic hypersthene gneisses. Roughly it is composed of quartz, ferromagnesians, and felspars in the proportions 10 : 25 : 65. About 40 per cent of the felspar in this rock is of the alkali variety. The rock may be described as a granulitic quartz-monzonite.

All gradations from this rock to one with practically no ferromagnesians are found. Alkali felspars in the more acid types are greatly in excess of the soda-lime ones. An intermediate type, where ferromagnesians are present in small amount, might be described as a granulitic quartz-bearing hypersthene-syenite. With the virtual disappearance of the ferromagnesian minerals the rock becomes a gneissic soda-granite. On the whole the more acid the rock the more it has been affected by subsequent soda solutions.

VI.—GNEISSIC SODA-GRANITES.

Associated with the hypersthene gneisses, and frequently developed along their margin, are numerous masses of medium-grained grey gneiss. As far as could be judged, there is a gradual passage from the rather coarse hypersthene-bearing rock to the much finer grained grey gneiss.

In the hand specimen (46/293) the rock is fresh and even-grained. It is composed of a pale felspathic matrix, in which are scattered numerous dark grains of quartz.

The microscopic texture is somewhat granulitic, but the grains frequently interlock, and are rarely rounded. Occasionally large porphyritic masses of potash felspar are present. True mortar structures do not occur in these rocks, but a fine granular aggregate

of quartz and felspar frequently separates the larger grains in the rock. Brush polarization, distorted twins, and cracks in the larger mineral grains are all common.

Myrmekitic intergrowths between the potash and the soda felspars are everywhere seen. They eat conical holes into the potash felspar and doubtless weaken the border zone much as pholases boring in hard rocks weaken and ultimately destroy them. By the break-up of this zone the greater part of the granular aggregate separating the larger crystals is formed.

I attribute the much finer grain of these rocks, compared with the hypersthene-granite-gneisses, to the weakening of the large porphyritic felspars in the process of albitization. The resultant weakness of the larger crystals has greatly accelerated their reduction to finer particles by the regional crushing forces.

Ferromagnesian minerals.

These rocks are almost devoid of ferromagnesian minerals. The only one which is at all common is biotite, and this is always present in minute quantities. When present it is generally partly replaced by iron-ore (24,428). In one specimen (24,446) I noted a cruciform twin believed to be zoisite, surrounded by a mass of biotite and muscovite. As the epidote minerals do not ordinarily occur in these rocks this is rather remarkable. Probably the whole mass of biotite and zoisite was a xenolith.

Salic minerals.

The gneissic soda-granites are almost entirely composed of felspar with a little quartz. Potash and soda felspars are present in varying proportions, but in an average specimen they are both present in equal amounts. Both perthite and microcline are common, but the former predominates. All the potash felspars show the microperthitic structures characteristic of charnockite.

As in the hypersthene-gneisses the potash felspar seems to have crystallised early, and to have been later replaced extensively by soda felspar. The perthite is always much corroded and one frequently sees large crystals of it split into several smaller ones by myrmekitic growths (23,230 A). Where the replacement is almost complete one sometimes sees a large crystal of albite pseudomorphic after microcline and containing large irregular relics of that mineral in its interior (23,230 B). Sometimes large potash felspars are so eaten away that they present an amoeba-like appearance (Pl. 21, fig. 2).

Albite, oligoclase, and myrmekite are all present in abundance in these rocks, but they present no features which have not already been described in connection with the hypersthene-gneisses. The quartz in these rocks generally shows the rod-like inclusions seen in charnockite.

Iron-ore, apatite, and zircon.

Iron-ore, apatite, and zircon are all rather common, but rarer than in the hypersthene-gneisses. Their mode of occurrence is identical in both cases, and their relative scarcity in these soda-granites is probably due to the absence of ferromagnesians, round which these minerals tend to cluster.

VII.—ANALYSES OF THE MALAKANAGIRI GNEISSES.

Analysis No. 1 is of a specimen collected from the high hills north of Korukonda (18° 17′ : 81° 59′). No. 2 is of a rock collected from the hill one mile east of Potrelu (18° 16′ : 82° 2′). Both rocks come from the igneous *massif* which extends eastwards from near Malakanagiri to within three miles of the main charnockite range of the Eastern Ghats. (Analyst—Mahadeo Ram.)

No. 1 is probably as basic as any of the rocks here. No. 2 is typical of the acid rocks in the outlying parts of this *massif* descibed elsewhere as gneissic soda-granites. Most of the rocks in this *massif* would have a chemical composition intermediate between these two extremes.

	49/571 No. 1.	46/293 No. 2.
SiO_2	58·58	73·40
Al_2O_3	16·18	14·30
Fe O	1·97	0·78
Fe_2O_3	7·46	1·05
MgO	2·29	0·04
CaO	5·04	1·54
Na_2O	3·50	6·66
K_2O	2·53	1·45
H_2O+	0·08	0·46
H_2O-	0·29	0·16
TiO_2	1·46	0·19
P_2O_5	0·70	0·17
MnO	0·11	Trace

The corresponding norms are as follows—

Quartz	11·58	26·40
Orthoclase	15·01	8·35
Albite	30·39	56·07
Anorthite	19·46	5·00
Corundum	0·31	..
Diopside	.	1·46
Hypersthene	15·73	0·41
Magnetite	2·78	1·16
Ilmenite	2·74	0·30
Apatite	1·68	0·34

As regards the norm of No. 1 the calculated percentage of lime felspar is probably too high, as some of the lime has been used up in the formation of hornblende, which mineral is rather abundant in the mode. After allowing for this the percentages of the quartz, felspar, ferromagnesian and other minerals shown in the norm is much the same as that estimated microscopically for the mode.

As regards the norm of No. 2 the mafic minerals shown are probably represented by biotite and iron-ore in the mode. The large percentage of albite shown probably occurs partly intergrown with a potash felspar in the perthite, partly as albite and myrmekite, and partly with anorthite to form oligoclase. The ratio of felspar to quartz in the norm differs little from that observed in the mode.

In the graphs on pl. 23 I have plotted the percentages of the various oxides in a series of charnockites against their silica contents. These analyses have been made of specimens collected from localities in Ceylon, from St. Thomas' Mount, from the Shevaroy hills, and from Pallavaram in Madras. The analyses are by H. S. Washington (1929, p. 481) R. J. C. Fabry (1929, p. 481) and J. T. Donald (1929, p. 481). Along with these I have also plotted the two analyses of the Malakanagiri rocks by Mahadeo Ram.

This procedure is open to all sorts of criticism. The most that can be hoped for it is to get a general idea of the differentiation of the charnockites. Even for this the number of analyses, especially towards the basic end, is inadequate.

The range of variation among the analyses, even from a single area like Ceylon, is very considerable. The graphs drawn are intended to be an average of the various analyses. In the Malakanagiri hypersthene-gneiss the soda and alumina are above average, iron is below, while potash, lime and magnesia are about normal. The high soda and alumina may be due to the introduction of albite

by soda solutions in the end stages of consolidation. On the other hand the difference from normal is well within the limits of variation shown by the other analyses, so that there is really no evidence to show that the high soda in this case is not a mere local abnormality.

In the analysis of the more acid of the Malakanagiri rocks the soda and alumina are far too high and the potash much too low. The differences greatly exceed the limits shown by the other analyses. If this rock can be regarded as a charnockite at all, and the field evidence strongly favours that view, soda and alumina must have been added to it and potash removed. This in my opinion is due to albitization in the final stages of consolidation.

VIII.—THE CHARNOCKITES OF MALAKANAGIRI AND ST. THOMAS' MOUNT.

A comparison of the hypersthene-gneiss of Malakanagiri with the charnockite of St. Thomas' Mount shows many similarities and some differences.

Though they occur hundreds of miles apart, both are intrusions in much older gneisses, form similar hill masses, and are indistinguishable in hand specimens. Moreover both are closely associated with norites and with acid granulites free from hypersthene.

Microscopic examination shows that the hypersthene, the microperthitic potash felspars, and the acicular inclusions in the quartz, which are considered characteristic of charnockite, also occur in the Malakanagiri rocks. The presence of 'quartz de corrosion' or myrmekite and of the accessory minerals apatite and zircon, are further points in common.

The only difference in field occurrence between these two rocks is that the Malakanagiri ones have been definitely crushed subsequent to their consolidation, whereas the Madras charnockites have not noticeably suffered in this way, though Sir T. H. Holland (1900, p. 154), expresses the opinion that their granulitic texture is due to movement in the last stages of crystallization.

Texturally they differ in that the hypersthene-gneiss is porphyritic, and shows distinct signs of cataclasis, whereas the charnockite is granulitic, and there is no obvious cataclasis.

Cataclastic phenomena are of little genetic importance, as they are secondary. The greatest difference between the two sets of

rocks lies in the porphyritic nature of the one as compared with the granulitic texture of the other. The granulitic texture of the Madras charnockite is according to Holland not an original feature, and therefore is not of any great significance. In any event accepted charnockites having a porphyritic texture occur in parts of Madras and in the Eastern Ghats, as well as in Malakanagiri. The slight textural differences may therefore be disregarded.

As far as general composition is concerned there is nothing in the hypersthene-gneiss analysis from Malakanagiri to prevent it being a charnockite. Microscopic examination confirmed by the chemical analyses shows that soda felspars and apatite are more common in the rocks of this area than in the Madras ones, but I think this is adequately explained by the albitization which they have suffered during their consolidation.

The resemblance between the Malakanagiri gneiss and charnockite in occurrence, mineralogy, and composition is very striking. The points of difference are small, unimportant, and readily explained. I, therefore, regard these gneisses as true members of the charnockite series. They occur within three miles of the vast charnockite boss of the Eastern Ghats, and are almost certainly apophyses from it. These views are not new nor revolutionary, but have been expressed by all field workers in the region west of the Ghats. They may be accepted without reserve.

IX.—IGNEOUS NATURE OF THE MALAKANAGIRI CHARNOCKITES.

Sir T. H. Holland, who first described the charnockite series, regarded its rocks as igneous. He considered (1900, p. 242) that their textural and mineralogical characters were original features due to their igneous origin, which had been little affected by subsequent metamorphism. Most geologists who have worked on the charnockite series in India have agreed with Holland in a general way, though instances of charnockites which have been considerably metamorphosed, especially by crushing, have been described.

Mr. E. Vredenburg (1918, pp. 423-448) in the year 1918 put forward the theory that the charnockites in Mysore were the high grade metamorphic derivatives of the great basic igneous series of that region. About the same time Dr. F. L. Stillwell (1918, pp. 128-130, 138-139, 190-192) advanced somewhat similar ideas, about

the charnockite-like rocks found by him in Adelie Land. More recently Mr. A. W. Groves (1933, pp. 150-208) has given an account of charnockite-like rocks in Uganda and has put forward a formidable array of chemical and petrological facts to prove that these rocks were formed by the plutonic metamorphism of a normal series of plutonic rocks.

The chemistry of the Malakanagiri gneisses and charnockites is not well enough known to permit a comparison with that of the similar Uganda rocks, but the field and petrological characteristics of the Malakanagiri rocks are known, and I think they suffice to prove conclusively that the charnockites of this region are slightly altered igneous rocks like those described by Holland in Madras, and not intensely metamorphosed igneous rocks like those described by Groves in Uganda.

One of Groves' main points is that there is a gradual passage from gneisses to charnockites. In Malakanagiri the charnockite hills often rise like igneous plugs 1,000 feet above the flat plain of felspathic gneiss. The actual junction is rarely seen, owing to the dense forest and debris, but its position can be fixed within a few yards. The change from one rock to another is, therefore, quite sharp in contrast to the very gradual change noted in Uganda.

Moreover, both acid and basic charnockites in Malakanagiri are surrounded by a uniform granitic gneiss. It is difficult to see how any metamorphic process could produce two rocks of totally different composition from a uniform granitic gneiss. The position in Uganda is quite different. There the gneisses are chemically almost identical with the charnockite-like rocks said to be their metamorphic equivalents.

All are agreed that metamorphic hypersthene is only found in rocks of the highest metamorphic grade. Such a grade may be due to regional or thermal causes. I have shown (pp. 407-408) that the regional metamorphism in Malakanagiri is always relatively low nor are there any important intrusions there which could have thermally metamorphosed the charnockites. It is difficult to see how they could ever have been raised to a temperature high enough to produce hypersthene.

The dolerite dykes are of some interest in this connection. Groves describes how similar rocks in passing from gneiss to charnockite exhibit all the stages of metamorphism from a dolerite to

a rock with all the minerals characteristic of charnockite. In Malakanagiri dolerite dykes are equally unmetamorphosed in gneiss and in charnockite, for they always retain their ophitic texture and original augite.

The evidence from the texture of the Malakanagiri charnockites is also against the metamorphic theory. The occurrence in these rocks of large idiomorphic potash felspars is widespread. This is a feature only found in igneous rocks which have been little metamorphosed or not at all. Where igneous rocks have been subjected to high grade metamorphism, the potash felspar ceases to be idiomorphic and becomes xenoblastic with respect both to albite and quartz (see Harker, 1932, p. 38). It is noteworthy that true idiomorphic felspars have not been found in Uganda.

Groves makes a strong point in favour of the metamorphic origin of his rocks when he shows that the appearance of the successive ferromagnesian minerals, as seen in reaction rims, is in the reverse of the accepted order for plutonic rocks. The reaction rims round the ferromagnesians in the Malakanagiri charnockites appear to be always in the right order.

The field evidence shows the sharp and probably intrusive junction between the Malakanagiri gneisses and charnockites, and makes it clear that low grade metamorphism is the rule throughout this area. It also shows that charnockites of different chemical composition are surrounded by a uniform granitic gneiss.

The internal evidence shows idiomorphic felspars which could only occur in a normal igneous rock. This evidence is strengthened by the presence of reaction rims of a kind commonly found in cooling rocks, ones moreover which would be unlikely to survive any important rise in temperature.

It seems impossible, therefore, to avoid the conclusions that the metamorphism of the charnockite here is low, that the charnockite is not the product of metamorphism of older plutonic rocks but a normal igneous rock, and that the hypersthene in it is of pyromorphic origin.

As the Malakanagiri rocks are almost certainly apophyses from the main charnockite mass and as no evidence of high grade metamorphism has been found in the charnockites of that mass, it is probable that these conclusions apply equally to most of the charnockites in the Eastern Ghats.

X.—ALBITIZATION IN MALAKANAGIRI.

In previous Chapters I have vaguely referred the development of myrmekite, biotite, and hornblende to albitization of the original rocks, but have expressed no opinion as to the nature of this phenomenon.

The first-formed minerals in the hypersthene-gneisses were felspars, pyroxenes, quartz, and perhaps iron-ore, none of which contain appreciable water. At a later date hornblende and biotite reaction rims have developed around the earlier pyroxenes, and albite has grown at the expense of potash felspar, usually with myrmekite as an intermediate stage. Moreover, it is clear from the comb-like structure of the biotite and hornblende, as well as from their relatively high water content, that they must have developed in an aqueous medium. It remains to discuss the myrmekite.

At first sight it would seem possible that the development of myrmekite and albite from potash felspars could be the result of uneven stress in the rock. It might easily be claimed, for instance, that the myrmekite was corroding the potash felspar at points of maximum stress.

If this were the case there should be little or no change in the general composition of the rock. If myrmekite and albite are to develop from potash-felspar, some soda must be introduced. This might come from soda-bearing minerals within the rock or from external sources. That the latter source is the right one is shown by the analyses of the rocks (p. 31) and by the fact that none of the soda-bearing minerals in the rock show any signs of decay.

This seems to rule out stress as the main reason for the development of myrmekite. This is borne out by field experience, for rocks, similar in composition to the Malakanagiri ones, which have been severely crushed, do not contain myrmekite. This is well seen in the acid charnockites of the main range. These have been severely stressed, but there is no myrmekite, and there are no large coronas of biotite or hornblende. Instead there is a considerable development of garnet.

If the myrmekite is not due to stress what is its origin?

The hypersthene-gneisses and soda-granites have been somewhat crushed, and contain numerous fine cracks through which water could readily pass. Water must have been present to enable biotite and hornblende to develop in the way they have done. That the formation of albite from potash-felspar also took place in the presence

of water is proved by the numerous inclusions of sericite in the albite. For albite and potash felspar contain no water but sericite does. It follows that the development of albite from perthite must have taken place in an aqueous medium, for otherwise there could have been no sericite; and as sericite has in many cases been deposited all the time during which the albite was developing from the potash felspar, it follows that there must have been a continuous supply of water at the contact. This means that there was a regular circulation of water in the rock while albitization was taking place.

I have already shown (p. 40) that the soda for the development of albite came from sources outside the rock. It seems almost certain that it was introduced into the rock in solution in the water circulating through it while albitization was taking place. This water probably corroded the potash felspars, the potash being leached out and the soda taking its place. Hence the great development of myrmekite and albite.

When the resulting alkali-rich waters came into contact with hypersthene an immediate reaction took place, followed by the development of coronas of hornblende and biotite.

Apatite.

Apatite occurs in the hypersthene-gneisses as minute idiomorphic crystals included in the first formed felspars, and as relatively large rounded masses associated with biotite and iron-ore.

In most charnockites the apatite occurs in the first form, and in very small amount. The rounded masses are therefore peculiar to the Malakanagiri ones, and probably account for their high phosphorus content (*see* p. 420).

It is reasonable to consider the idiomorphic apatites as primary and the others as secondary. The probability seems to be that the rounded masses have been introduced by the same solutions which have given rise to the myrmekite and albite. My chief reason for this view is that the rounded apatite is generally closely associated with biotite and iron-ore. These two minerals occur both as reaction products between the alkali liquids and the primary ferromagnesians, and as deposits along cracks. They must have been carried along by the liquid, for otherwise they could not occur so frequently along cracks. The association of the apatite with these two suggests that it has also been transported by the same liquid.

The rounded shape of the apatite masses is possibly the result of their having filled cavities corroded in the original minerals of the rock by the alkali waters.

Iron-ore.

Iron-ore, like apatite, seems to have been frequently transported by the alkali waters. Whether it has been taken into solution by the alkali water from the rock itself and later redeposited, or whether it has been introduced from external sources, is impossible to say.

Quartz, too, is probably partly original, partly a by-product of the corrosion of perthite, and partly introduced, but it is rarely possible to say what its origin is in particular cases.

Source of soda-bearing fluids.

The waters which have brought about these secondary alterations in the Malakanagiri gneisses cannot have been surface waters, for these would have brought about changes in which biotite coronas and myrmekite could have taken no part. They must therefore have been of deep-seated origin. They must also have been widespread, for rocks altered in the same way are believed to occur all along the western margin of the main charnockite range. The age of the alkali waters must be younger than that of the charnockite apophyses in southern Jeypore and older than that of the dolerites, for these have not been albitized.

The only source which would satisfy these conditions is the charnockite itself. This is deep-seated and widespread, and, like other igneous masses, probably extruded alkali waters in the final stages of its consolidation. This would probably have taken place after the consolidation of the Malakanagiri intrusions, and would certainly have been earlier than the dolerites.

It is most probable that the albitization was effected by waters driven off from the main charnockite intrusion in the final stages of its igneous activity. This would account for the widespread occurrence of these phenomena.

Albitization of the older gneisses and schists.

A very similar albitization seems to have affected the biotite-gneisses and hornblende-schists along the charnockite border. Probably the same liquid from the charnockite was responsible for this also. The effects of the alkali waters on the gneisses and schists are not so conspicuous as those described in the hypersthene-gneisses, but they are of the same kind. No doubt the total change in composition brought about in this way has been large.

I have no clear ideas as to the nature of the alkali solutions. They must have been rich in alkalis, and probably carried much silica, iron, and phosphorus. The common occurrence of gold in the streams draining the gneisses and schists along the western margin of the Eastern Ghats suggests that it may have been introduced into these rocks in the same way, but there is no certainty on this point.

Nature of the alkali solutions.

XI.—THE KHONDALITES.

The main charnockite range is believed to be practically entirely igneous. Here and there patches of sillimanite-bearing rocks have been found in it, but only on a small scale, such as might be expected in the contact zone of any igneous intrusion.

It is not till the hills on the south-eastern side of the Machkund valley are reached that khondalites are extensively found. No effort was made in the field to map the boundary of the khondalites exactly, as this was outside the scope of my work. A few specimens were, however, collected in various localities. Slides of these show that they are similar in essentials to other khondalites. In some cases (23246) they contain abundant orthoclase, in others (23248 and 23249) enstatite and rutile were noticed. The ferromagnesian minerals and also the sillimanite are much altered to serpentine.

The metamorphic grade of these rocks has never been questioned. They are essentially sillimanite-garnet-graphite-quartz schists, and must have been subjected to a high grade of metamorphism. The serpentine is probably a sign of later retrograde metamorphism.

A perusal of the literature on the charnockites and khondalites shows that those geologists who have studied them in the field all agree on the importance of stress in their development.

Thus Walker (1902, p. 10) holds that the khondalites are ancient sediments metamorphosed by great mountain-building forces, and by the numerous large igneous intrusions associated with them.

Smith (1900, p. 155) in discussing the khondalites of the Ganjam district says 'Since the consolidation of the gneisses much crushing has taken place. The folding that then occurred evidently enveloped large masses of the sedimentary rocks'.

Holland (1900, pp. 240-241) claims that the charnockites of the Madras Presidency have been subjected to dynamo-metamorphism,

Mr. F. D. Adams (1929, p. 240) talks of movement of the charnockite magmas in the final stages of their consolidation, and I have shown how severely the rocks of the charnockite range in southern Jeypore have been crushed.

All these writers agree also that the chief movement took place towards the end of the charnockite period.

There is accordingly every reason to suppose that mountain building was active in Ceylon, Southern India, and in the Eastern Ghats in late charnockite times. In the course of this the thick mass of aluminous sediments, which now forms the khondalites, was probably folded into the partly liquid charnockite, and may there have received its high-grade metamorphic imprint. Some reaction may have taken place between the magma and the sediments, leading to the final development of hypersthene in the charnockite rather than the usual pyroxene.

The whole charnockite region has been exposed to denudation since Archæan times. It is not surprising, therefore, that the only remains of the original sedimentary series are a few synclines of khondalites.

As regard the age of the khondalites there is of course no definite evidence, but andalusite-schists are found in great abundance among the Archæan sediments of the region lying to the west of the Eastern Ghats, and I think it possible that they are the same series as the khondalites, but in a lower grade of metamorphism.

Sir L. L. Fermor (1935, p. 48) insists on the necessity of relative uplift of the charnockite region of the Eastern Ghats with respect to the Archæan rocks further to the west, because he considers its high grade metamorphic imprint could only have been acquired at a great depth, although now it is actually higher than the region further to the west. He considers that a fault along the western margin of the Eastern Ghats is the most probable way in which such relative elevation could have occurred.

I think it likely that faults and overthrusts would occur as the result of mountain-building forces, and that the khondalites may in some cases have been elevated by these, but neither I nor any of the other field workers in the khondalite region have taken Fermor's view of the origin of the high grade of metamorphism found there. The commonest view (*see* pp. 403 and 404) is that the metamorphism is thermal; the influence of stress is also emphasized.

XII.—SUMMARY.

The author visited southern Jeypore in 1934 and in 1935 to map a part of the western margin of the Eastern Ghats. The chief object was to ascertain whether the Eastern Ghats are separated from the region further west by a boundary fault. The mapping has shown that the boundary of the great charnockite mass of the Eastern Ghats is everywhere irregular, and that numerous intrusions belonging to the charnockite series occur in the country immediately to the west of the main range. The boundary is considered to be a normal intrusive one. There is no reason whatever to suppose that the margin of the charnockite is a great fault.

The various older rocks lying along the western border of the main charnockite boss are described shortly, and it is shown that their grade of metamorphism is low to medium, with increasing stress phenomena as the Eastern Ghats are approached. The newer dolerites of the same area are also described.

Next, the charnockites in the main range are discussed, and their metamorphism is shown to be similar to that of the older gneisses further to the west, but with even more marked stress phenomena.

An account, with analyses, is then given of the hypersthene-gneisses and gneissic soda-granites which occur as intrusions in the older gneisses, and it is shown that they closely resemble Holland's charnockite, and are besides indistinguishable from some of the accepted charnockites of the main range. It is concluded that they are undoubted members of the charnockite series.

The hypersthene-gneisses are proved to be of igneous origin. They have been slightly crushed after their consolidation, and some of the minerals of which they are composed have been corroded and partially replaced by a subsequent invasion of alkaline solutions. Their grade of metamorphism is, however, low.

As hypersthene in metamorphosed igneous rocks is confined to rocks of the highest grade, it is concluded that the hypersthene in these rocks is not metamorphic but pyromorphic.

The interesting effects brought about by the passage of alkali solutions through all the rocks west of the main range are described, and it is shown that these solutions were of magmatic origin, and were given off by the main charnockite mass in the final stage of its consolidation.

The last chapter is devoted to the khondalites which lie further to the east, and were not mapped in detail. It is thought that

they are ancient aluminous sediments involved in mountain-building, and later invaded by huge igneous intrusions, the charnockites. It is probably to the heat from these intrusions that their admittedly high grade of metamorphism is to be ascribed. It is considered that they may be the high grade metamorphic representatives of the less altered aluminous sediments so abundant in the Archæans lying further west in Bastar State.

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XIV.—EXPLANATION OF PLATES.

PLATE 20, FIG. 1. Slightly crushed charnockite. Note the linear arrangement of the various minerals.

FIG. 2. The centre shows one of the felspathic patches in Fig. 1 under crossed nicols. The granulation and discontinuity of the twinning planes is due to crushing and movement.

FIG. 3.—Charnockite similar to that shown in Fig. 1, but more intensely crushed. Most of the hypersthene is altered to a feathery aggregate of scaly hornblende.

FIG. 4.—Completely crushed charnockite, consisting of narrow bands of hornblende (dark), felspar, etc. (light) and garnet (G). A few crystals of hypersthene (H) always seem to have survived the crushing.

PLATE 21, FIG. 1.—Typical hypersthene-gneiss.

FIG. 2.—Typical soda-granite.

FIG. 3.—Biotite-gneiss with porphyritic crystals of orthoclase (Or).

FIG. 4.—Same slide as Fig. 3, with nicols crossed, showing myrmekite (M) corroding the orthoclase (Or).

PLATE 22, FIG. 1.—Myrmekite corroding microcline.

FIG. 2.—Dactylites of biotite and a myrmekitic intergrowth of biotite and albite.

FIG. 3.—Dolerite with margins of augite crystals uralitized and in some cases altered to garnet.

FIG. 4.—Pyroxenite with allanite.

PLATE 23.—Variation diagram of the charnockite series.

PLATE 24.—Geological map of a part of Southern Jeypore, Orissa.

MISCELLANEOUS NOTE.

Quarterly Statistics of production of Coal, Gold and Petroleum, in India and Burma : April to June, 1938.

Coal.

——	April.	May.	June.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	24,869	22,900	23,121	70,890
Baluchistan	1,419	905	612	2,936
Bengal	689,855	626,582	579,847	1,896,284
Bihar	1,350,699	1,242,026	1,220,554	3,813,279
Orissa	3,031	2,449	3,075	8,555
Central Provinces . . .	150,004	136,358	134,918	421,280
Punjab	20,249	17,251	9,880	47,380
TOTAL .	2,240,126	2,048,471	1,972,007	6,260,604

Gold.

- -	April.	May.	June.	Quarterly total for each Company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	7,937	8,188	7,936	24,061
The Champion Reef Gold Mines of India, Ltd.	5,786	5,988	5,785	17,559
The Ooregum Gold Mining Company of India, Ltd.	4,067	4,170	4,156	12,393
The Nundydroog Mines, Ltd. .	8,103	8,373	8,102	24,578
TOTAL .	25,893	26,719	25,979	78,591

Petroleum.

	Crude Petroleum.	Total gasolene from natural gas.*
	Gallons.	Gallons.
Assam	16,441,005	*Nil.*
Punjab	2,060,740	113,016
TOTAL	18,501,745	113,016
Burma	69,391,531	2,621,161

* These figures represent the total amounts of gasolene derived from natural gas at the well-head. Of these amounts, a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries. The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous Records.

A. M. HERON.

MGIPC—M—VIII-1-14—19-10-38—820.

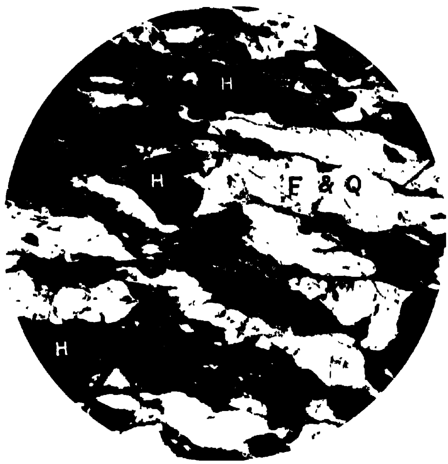


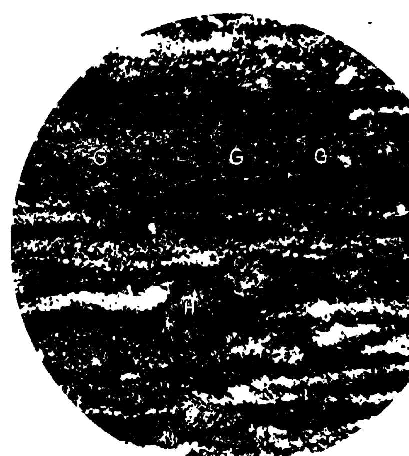
FIG. I. SLIGHTLY CRUSHED CHARNOCKITE. NOTE THE LINEAR ARRANGEMENT OF THE VARIOUS MINERALS

H — Hypersthene F — Felspar Q — Quartz.

FIG. 2. THE CENTRE SHOWS ONE OF THE FELSPATHIC PATCHES IN FIG. I UNDER CROSSED NICOLS. THE GRANULATION AND DISCONTINUITY OF THE TWINNING PLANES IS DUE TO CRUSHING AND MOVEMENT.

H. Crookshank & S. N. Das., Photos

FIG. 3. CHARNOCKITE SIMILAR TO THAT SHOWN IN FIG. 1, BUT MORE INTENSELY CRUSHED. MOST OF THE HYPERSTHENE IS ALTERED TO A FEATHERY AGGREGATE OF SCALY HORNBLENDE.



G. S. I., Calcutta

FIG. 4. COMPLETELY CRUSHED CHARNOCKITE, CONSISTING OF NARROW BANDS OF HORNBLENDE (DARK), FELSPAR, ETC. (LIGHT) AND GARNET (G). A FEW CRYSTALS OF HYPERSTHENE (H) ALWAYS SEEM TO HAVE SURVIVED THE CRUSHING.

FIG. 1. TYPICAL HYPERSTHENE-GNEISS
Or - Orthoclase (Perthite)
H - Hypersthene
B = Biotite.

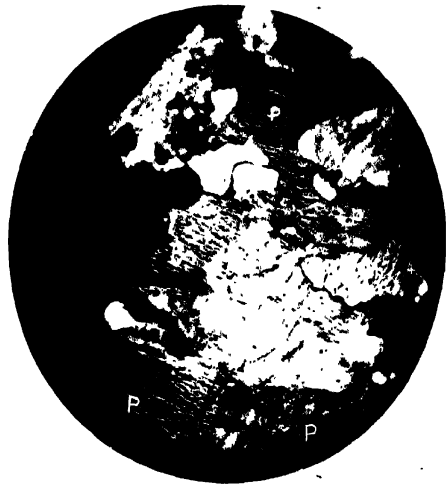
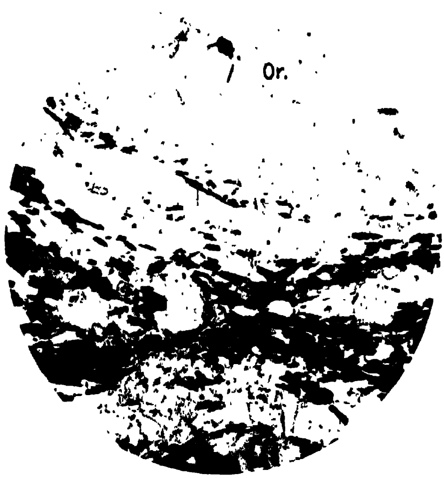


FIG. 2. TYPICAL SODA-GRANITE.
P Orthoclase (Perthite)
M - Myrmekite
Q - Quartz
A -- Albite.



H. Crookshank & S. N. Das, Photo. *G. S. I., Calcutta.*

FIG. 3. BIOTITE-GNEISS WITH PORPHYRITIC CRYSTALS OF ORTHOCLASE (Or).

FIG. 4. SAME SLIDE AS FIG. 3, WITH NICOLS CROSSED, SHOWING MYRMEKITE (M) CORRODING THE ORTHOCLASE (Or).

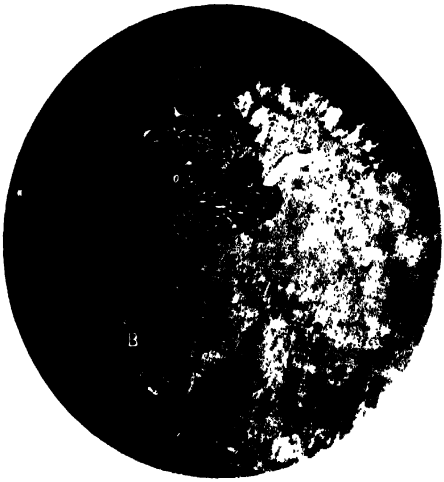


FIG. 1. MYRMEKITE CORRODING MICROCLINE.

F = Microcline A = Albite
B = Biotite M = Myrmekite.

FIG. 2. DACTYLITES OF BIOTITE AND A MYRMEKITIC INTERGROWTH OF BIOTITE AND ALBITE.

Or = Orthoclase A = Albite
B = Biotite M = Intergrowth of Biotite and Albite.

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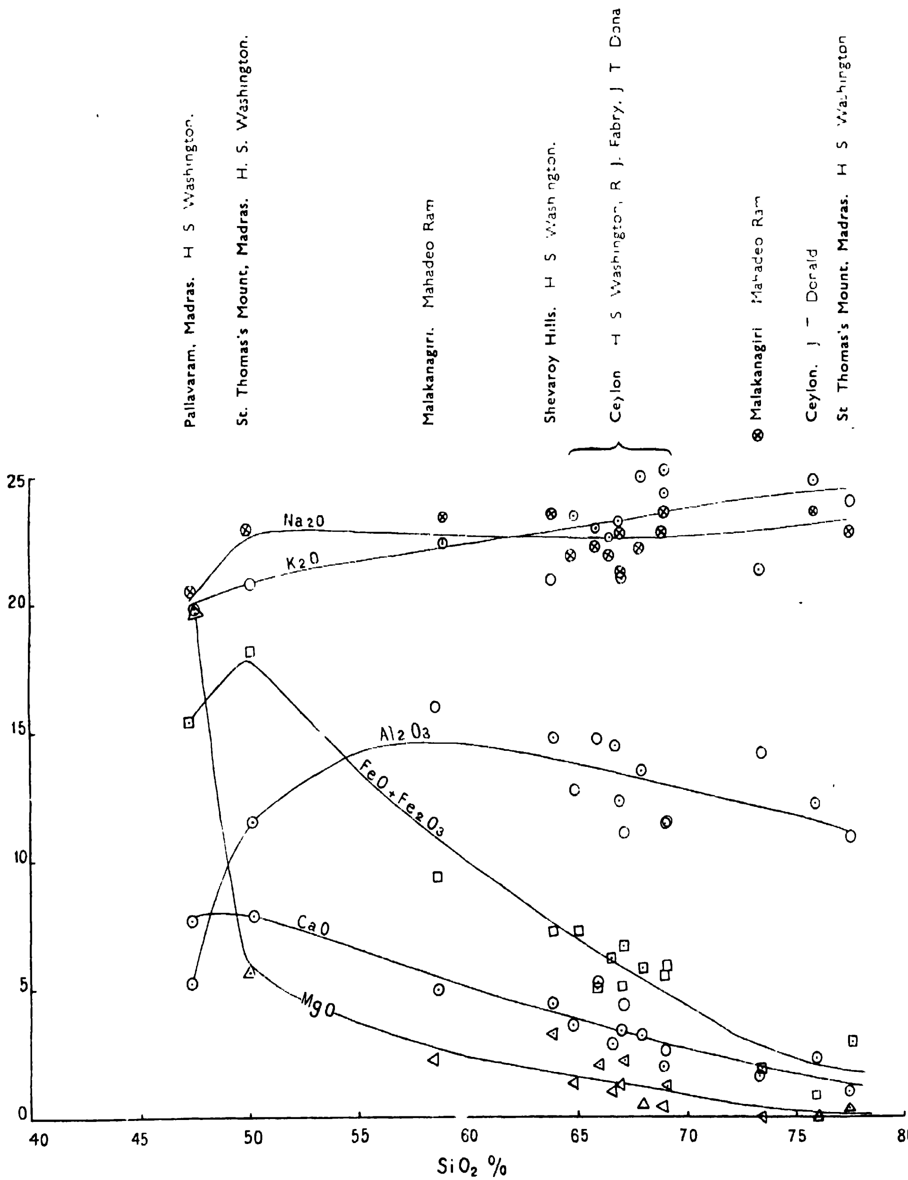
FIG. 3. DOLERITE WITH MARGINS OF AUGITE CRYSTALS URALITIZED AND IN SOME CASES ALTERED TO GARNET.

G = Garnet L = Labradorite
A = Augite U = Uralite.

FIG. 4. PYROXENITE WITH ALLANITE.

P = Pyroxene
A = Allanite.

Records, Vol. 73, Pl. 23.



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VARIATION DIAGRAM OF THE CHARNOCKITE SERIES.

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA.

Vol. I, 1868.

Part 1 (out of print).—Annual report for 1867. Coal-seams of Tawa valley. Coal in Garrow Hills. Copper in Bundelkhund. Meteorites.

Part 2 (out of print).—Coal-seams of neighbourhood of Chanda. Coal near Nagpur. Geological notes on Surat collectorate. Cephalopodous fauna of South Indian cretaceous deposits. Lead in Raipur district. Coal in Eastern Hemisphere. Meteorites.

Part 3 (out of print).—Gastropodous fauna of South Indian cretaceous deposits. Notes on route from Poona to Nagpur *viâ* Ahmednuggur, Jalna, Loonar, Yeotmahal, Mangali and Hingunghat. Agate-flake in pliocene (?) deposits of Upper Godavary. Boundary of Vindhyan series in Rajputana. Meteorites.

Vol. II, 1869.

Part 1 (out of print).—Valley of Poorna river, West Berar. Kuddapah and Kurnool formations. Geological sketch of Shillong plateau. Gold in Singhbhum, etc. Wells at Hazareebagh. Meteorites.

Part 2 (out of print).—Annual report for 1868. Pangshura tecta and other species of Chelonia from newer tertiary deposits of Nerbudda valley. Metamorphic rocks of Bengal.

Part 3 (out of print).—Geology of Kutch, Western India. Geology and physical geography of Nicobar Islands.

Part 4 (out of print).—Beds containing silicified wood in Eastern Prome, British Burma. Mineralogical statistics of Kumaon division. Coal-field near Chanda. Lead in Raipur district. Meteorites.

Vol. III, 1870.

Part 1 (out of print).—Annual report for 1869. Geology of neighbourhood of Madras. Alluvial deposits of Irrawadi, contrasted with those of Ganges.

Part 2 (out of print).—Geology of Gwalior and vicinity. Slates at Chiteli, Kumaon. Lead vein near Chicholi, Raipur district. Wardha river coal-fields, Berar and Central Provinces. Coal at Karba in Bilaspur district.

Part 3 (out of print).—Mohpani coal-field. Lead-ore at Slimanabad, Jabalpur district. Coal, east of Chhattisgarh between Bilaspur and Ranchi. Petroleum in Burma. Petroleum locality of Sudkal, near Futtijung, west of Rawalpindi. Argentiferous galena and copper in Manbhum. Assays of iron ores.

Part 4 (out of print).—Geology of Mount Tilla, Punjab. Copper deposits of Dalbhum and Singhbhum: 1.—Copper mines of Singhbhum: 2.—Copper of Dalbhum and Singhbhum. Meteorites.

Vol. IV, 1871.

Part 1 (out of print).—Annual report for 1870. Alleged discovery of coal near Gooty, and of indications of coal in Cuddapah district. Mineral statistics of Kumaon division.

Part 2 (out of print).—Axial group in Western Prome. Geological structure of Southern Konkan. Supposed occurrence of native antimony in the Straits Settlements. Deposit in boilers of steam-engines at Raniganj. Plant-bearing sandstones of Godavari valley, on southern extensions of Kamthi group to neighbourhood of Ellore and Rajmandri, and on possible occurrence of coal in same direction.

Part 3 (out of print).—Borings for coal in Godavari valley near Dumagudem and Bhadrachalam. Narbada coal-basin. Geology of Central Provinces. Plant-bearing sandstones of Godavari valley.

Part 4 (out of print).—Ammonite fauna of Kutch. Raipur and Hengir (Gangpur) Coal-field. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Vol. V, 1872.

Part 1 (out of print).—Annual report for 1871. Relations of rocks near Murree (Mari), Punjab. Mineralogical notes on gneiss of South Mirzapur and adjoining country. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Part 2 (out of print).—Coasts of Baluchistan and Persia from Karachi to head of Persian Gulf, and some of Gulf Islands. Parts of Kummummet and Hanamoonda districts in Nizam's Dominions. Geology of Orissa. New coal-field in south-eastern Hyderabad (Deccan) territory.

Part 3 (out of print).—Maskat and Massandim on east of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.

Part 4 (out of print).—Coal in northern region of Satpura basin. Evidence afforded by raised oyster banks on coasts of India, in estimating amount of elevation indicated thereby. Possible field of coal-measures in Godavari district, Madras Presidency. Lameta or intra-trappean formation of Central India. Petroleum localities in Pegu. Supposed eozoonal limestone of Yellam Bile.

Vol. VI, 1873.

Part 1.—Annual report for 1872. Geology of North-West Provinces.

Part 2 (out of print).—Bisrampur coal-field. Mineralogical notes on gneiss of south Mirzapur and adjoining country.

Part 3 (out of print).—Celt in ossiferous deposits of Narbada valley (Pliocene of Falconer): on age of deposits, and on associated shells. Barakars (coal-measures) in Beddadanole field, Godavari district. Geology of parts of Upper Punjab. Coal in India. Salt-springs of Pegu.

Part 4 (out of print).—Iron deposits of Chanda (Central Provinces). Barren Islands and Narkondam. Metalliferous resources of British Burma.

Vol. VII, 1874.

Part 1 (out of print).—Annual report for 1873. Hill ranges between Indus valley in Ladak and Shah-i-Dula on frontier of Yarkand territory. Iron ores of Kumaon. Raw materials for iron-smelting in Raniganj field. Elastic sandstone, or so-called Itacolumyte. Geological notes on part of Northern Hazaribagh.

Part 2 (out of print).—Geological notes on route traversed by Yarkand Embassy from Shah-i-Dula to Yarkand and Kashgar. Jade in Karakash valley, Turkistan. Notes from Eastern Himalaya. Petroleum in Assam. Coal in Garo Hills. Copper in Narbada valley. Potash-salt from East India. Geology of neighbourhood of Mari hill station in Punjab.

Part 3 (out of print).—Geological observations made on a visit to Chadderkul, Thian Shan range. Former extension of glaciers within Kangra district. Building and ornamental stones of India. Materials for iron manufacture in Raniganj coal-field. Manganese-ore in Wardha coal-field

Part 4 (out of print).—Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

Vol. VIII, 1875.

Part 1 (out of print).—Annual report for 1874. The Altum-Artush considered from geological point of view. Evidences of 'ground-ice' in tropical India, during Talchir period. Trials of Raniganj fire-bricks.

Part 2 (out of print).—Gold-fields of south-east Wynaad, Madras Presidency. Geological notes on Khareean hills in Upper Punjab. Water-bearing strata of Surat district. Geology of Scindia's territories.

Part 3 (out of print).—Shahpur coal-field, with notice of coal explorations in Narbada regions. Coal recently found near Moflong, Khasia Hills.

Part 4 (out of print).—Geology of Nepal. Raigarh and Hingir coal-fields.

Vol. IX, 1876.

Part 1 (out of print).—Annual report for 1875. Geology of Sind.

Part 2 (out of print).—Retirement of Dr. Oldham. Age of some fossil floras of India. Cranium of Stegodon Ganesa, with notes on sub-genus and allied forms. Sub-Himalayan series in Jamu (Jammoo) Hills.

Part 3 (*out of print*).—Fossil floras in India. Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Maleri and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.

Part 4 (*out of print*).—Fossil floras in India. Osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

VOL. X, 1877.

Part 1 (*out of print*).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheira in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Embydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (*out of print*).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (*out of print*).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (*out of print*).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis', McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

VOL. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (*out of print*).—Geology of Sind (second notice). Origin of Kumaon lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

Part 3 (*out of print*).—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

VOL. XII, 1879.

Part 1 (*out of print*).—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia. Siwalik beds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2 (*out of print*).—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3 (*out of print*).—Geological features of northern Madura, Padukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia speciosa, Royle (Sphenophyllum trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbudda.

Part 4.—"Attock Slates" and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1 (*out of print*).—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of North-Eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas'. Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain: and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danaite from Khetri mines, Rajputana; with remarks on Jaipurite (Syepoorite). Zinc-ore (Smithsonite and Blende) with barytes in Karnul district, Madras. Mud-eruption in island of Cheduba.

Part 3 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Unification of geological nomenclature and cartography. Geology of Arvali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah district, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district; (2) arsenical pyrites in same neighbourhood; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field. Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Gold-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kays (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosalpore, Jabalpur district. Umaria coal-field.

Part 3 (out of print).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussoorree. Cretaceous coal-measures at Borsora in Khasia Hills, near Laour in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1 (out of print).—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Kurnool district. Geology of Chuari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (out of print).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (out of print).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishâpûr, Khorassan. Fiery eruption from Mynbyin mud volcano of Cheduba Island, Arakan. Langrin coal-field, South-West Khasia Hills. Umaria coal-field.

Part 4 (out of print).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

Vol. XVIII, 1885.

Part 1 (out of print).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2 (out of print).—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (out of print).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthalla and Chandpur meteorites. Oil wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmein district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (out of print).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1 (out of print).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field notes. Section from Simla to Wangtu, and petrological character of Ambhibolites and Quartz-Diorites of Sutlej valley.

Part 2 (out of print).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruption rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-note from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2 (out of print).—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west, of Salt-range, in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Woolasten Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-fields, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part I.

VOL. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicyonodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive-group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal-fields of Lairungao, Meosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

VOL. XXIV, 1891.

Part 1 (out of print).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-spring near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (out of print).—Mammalian Bones from Mongolia. Darjiling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

VOL. XXV, 1892.

Part 1 (out of print).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dasht-i-Bedalot; with appendices on Chammans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Safêd Kôh. Jherria Coal-field.

Part 3 (out of print).—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (out of print).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Ambar-like Resin in Burma. Triassic Deposits of Salt-range.

VOL. XXVI, 1893.

Part 1 (out of print).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma, Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2 (out of print).—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (out of print).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Graphite in Tavoy and Mergui.

Part 4 (out of print).—Geology of country between Chappar Rift and Harnai in Baluchistan. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

Vol. XXVII, 1894.

Part 1 (out of print).—Annual report for 1893. **Bhaganwala Coal-field, Salt-range, Punjab.**

Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, **Hyderabad (Deccan).** Gohna Landslip, Garhwal.

Part 3 (out of print).—Cambrian Formation of Eastern Salt-range. *Giridih (Karharbari) Coal-fields. Chipped (?) Flints in* Upper Miocene of Burma. Velates **Schmideliana, Chemn.,** and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

Part 4 (out of print).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistan. Highly Phosphatic Mica Periodotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Periodotite in Bengal.

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.

Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.

Part 3 (out of print).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.

Part 4 (out of print).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyans. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

Vol. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.

Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwana-land". Notes.

Part 3.—Igneous Rocks from the Tochi Valley. Notes.

Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

Vol. XXX, 1897.

Part 1 (out of print).—Annual report for 1896. Norite and associated Basic Dykes and Lava flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.

Part 2.—Cretaceous Deposits of Pondicherri. Notes.

Part 3 (out of print).—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikaner. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.

Part 4 (out of print).—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Caut. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

Vol. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjiling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.

Part 2 (out of print).—Lt.-Genl. C. A. MacMahon. Cyclobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.

Part 3 (out of print).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.

Part 4 (out of print).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

Vol. XXXII, 1905.

Part 1.—Review of Mineral Production of India during 1898-1903.
Part 2 (out of print).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and U in Tibet. Bauxite in India. Miscellaneous Notes.
Part 3 (out of print).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites-Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.
Part 4.—Obituary notices of H. B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

Vol. XXXIII, 1906.

Part 1 (out of print).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.
Part 2 (out of print).—General report for 1905. Lashio Coal-field, Northern Shan States. Namma. Mansang and Man-se-le Coal-fields, Northern Shan States, Burma. Miscellaneous Notes.
Part 3 (out of print).—Petrology and Manganese-ore Deposits of Sausar Tahsil, Chhindwara district, Central Provinces. Geology of part of valley of Kanhan River in Nagpur and Chhindwara districts, Central Provinces. Manganite from Sandur Hills. Miscellaneous Notes.
Part 4 (out of print).—Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond-bearing Deposits. Index to Volume XXXIII.

Vol. XXXIV, 1906.

Part 1 (out of print).—Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan. Coal Occurrences in Foot-hills of Bhutan. Dandli Coal-field: Coal outcrops in Kotli Tahsil of Jammu State. Miscellaneous Notes.
Part 2 (out of print).—Mineral production of India during 1905. Nummulites Douvillei, with remarks on Zonal Distribution of Indian Nummulites. Auriferous Tracts in Southern India. Abandonment of Collieries at Warora, Central Provinces. Miscellaneous Notes.
Part 3 (out of print).—Explosion Craters in Lower Chindwin District, Burma. Laves of Pavagad Hill. Gibbsite with Manganese-ore from Talevadi, Belgaum district, and Gibbsite from Bhekowli, Satara District. Classification of Tertiary System in Sind with reference to Zonal Distribution of Eocene Echinoidea.
Part 4 (out of print).—Jaipur and Nazira Coal-fields, Upper Assam. Makum Coal-fields between Tirap and Namdang Streams. Kobat Anticline, near Seiktein, Myingyan district, Upper Burma. Asymmetry of Yenangyat-Singu Anticline, Upper Burma. Northern part of Gwegyo Anticline, Myingyan District, Upper Burma. Breynia Multituberculata, from Nari of Baluchistan and Sind. Index to Volume XXXIV.

Vol. XXXV, 1907.

Part 1 (out of print).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokachi and neighbourhood, Dacca district.
Part 2 (out of print).—Indian Aerolites. Brine-wells at Bawgyo, Northern Shan States. Gold-bearing Deposits of Loi Twang, Shan States. Physa Prinsepii in Maestrichtian strata of Baluchistan. Miscellaneous Notes.
Part 3.—Preliminary survey of certain Glaciers in North-West Himalaya. A.—Notes on certain Glaciers in North-West Kashmir.
Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

Vol. XXXVI, 1907-08

Part 1 (out of print).—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic outburst of Late Tertiary Age in South Hsenwi, N. Shan States. New suidæ from Bugti Hills, Baluchistan. Permo-Carboniferous Plants from Kashmir.

VOL. XXXVII, 1908-09.

VOL. XXXVIII, 1909-10.

VOL. XXXIX, 1910.

VOL. XL, 1910.

VOL. XLI, 1911-12.

Part 3.—Mineral Production of India during 1910. Samarskite and other minerals in Nellore District, Madras Presidency. Coal in Namchik Valley, Upper Assam. Miscellaneous Notes.

Part 4.—Pegu-Eocene Succession in Minbu District near Ngape. Geology of Henzada District, Burma. Geology of Lonar Lake, with note on Lonar Soda Deposit. International Geological Congress of Stockholm. Miscellaneous Notes. Index to Volume XLI.

Vol. XLII, 1912.

Part 1.—Survival of Miocene Oyster in Recent Seas. Silurian Fossils from Kashmir. Blödite from Salt Range. Gold-bearing Deposits of Mong Long, Hsipaw State, Northern Shan States, Burma. Steatite Deposits, Idar State. Miscellaneous Notes.

Part 2.—General Report for 1911. Dicotyledonous Leaves from Coal Measures of Assam. Poting Glacier, Kumaon, Himalaya, June 1911. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1911. Kodurite Series.

Part 4.—Geological Reconnaissance through Dehong Valley, being Geological Results of Abor Expedition, 1911-12. Traverse across the Naga Hills of Assam. Indian Aerolites. Miscellaneous Notes.

Vol. XLIII, 1913.

Part 1 (out of print).—General Report for 1912. Garnet as a Geological Barometer. Wolframite in Tavoy District, Lower Burma. Miscellaneous Notes.

Part 2 (out of print).—Mineral Production of India during 1912. Relationship of the Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Hambergite from Kashmir.

Part 3.—Contributions to the geology of the Province of Yünnan in Western China: I.—Bhamo-Têng-Yüeh Area. II.—Petrology of Volcanic Rocks of Têng-Yüeh District. The Kirna Hills. Banswal Aerolite.

Part 4.—Gold-bearing Alluvium of Chindwin River and Tributaries. Correlation of Siwalik with Mammal Horizons of Europe. Contributions to the Geology of the Province of Yünnan in Western China: III.—Stratigraphy of Ordovician and Silurian Beds of Western Yünnan, with Provisional Palæontological Determinations. Notes on "Camarocrinus Asiaticus" from Burma.

Vol. XLIV, 1914.

Part 1 (out of print).—General Report for 1913. Carbonaceous Aërolite from Rajputana. Nummulites as Zone Fossils, with description of some Burmese species.

Part 2.—Contributions to the Geology of the Province of Yünnan in Western China: IV.—Country around Yünnan Fu. Dyke of white Trap from Pench Valley Coal-field, Chhindwara District, Central Provinces. Mineral concessions during 1913.

Part 3.—Coal-seams near Yaw River, Pakokku District, Upper Burma. The Monazite Sands of Travancore. Lower Cretaceous Fauna from Himalayan Gieumal Sandstone together with description of a few fossils from Chikkim series. Indarctos salmontanus Pilgrim. Future Beheading of Son and Rer Rivers by Hasdo.

Part 4.—Salt Deposits of Cis-Indus Salt Range. Teeth referable to Lower Siwalik Creodont genus 'Dissopsalis' Pilgrim. Glaciers of Dhauli and Lissar Valleys, Kumaon, Himalaya, September 1912. Miscellaneous Notes.

Vol. XLV, 1915.

Part 1.—New Siwalik Primates. Brachiopoda of Namyau Beds of Burma. Miscellaneous Note.

Part 2.—General Report for 1914. Note on Sivælurus and Paramachærodus.

Part 3.—Mineral Production of India during 1914. Three New Indian Meteorites. Kuttippuram, Shupiyan and Kamsagar. Dentition of Tragulid Genus (Dorcabune). Hematite Crystals of Corundiform Habit from Kajlidongri, Central India.

Part 4.—Geology of country near Ngahlaingdwin. Geology of Chitral, Gilgit and Pamirs.

Vol. XLVI, 1915.

Quinquennial Review of Mineral Production of India for 1909 to 1913 (*out of print*).

Vol. XLVII, 1916.

Part 1.—General Report for 1915. Eocene Mammals from Burma. Miscellaneous Notes.

Part 2.—The Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Iron Ore Deposits of Twinngé, Northern Shan States.

Part 3.—Obituary: R. C. Burton. The Mineral Production of India during 1915. Fienmgostrea, an eastern group of Upper Cretaceous and Eocene Ostreidæ, with descriptions of two new species.

Part 4.—Contributions to the Geology of the Province of Yünnan in Western China: 5.—Geology of parts of the Salween and Mekong Valleys. A fossil wood from Burma. The Visuni and Ekh Khera Aerolites.

Vol. XLVIII, 1917.

Part 1.—General Report for 1916. A revised classification of the Gondwana System.
Part 2.—Mineral Production of India during 1916. Mammal collections from Basal Beds of Siwaliks.
Part 3.—Crystallography and Nomenclature of Hollandite. Geology and Ore Deposits of Bawdwin Mines. Miscellaneous Notes.
Part 4.—Biana-Lalsot Hills in Eastern Rajputana. Origin of the Laterite of Seoni, Central Provinces.

Vol. XLIX, 1918-19.

Part 1.—General Report for 1917. Cassiterite Deposits of Tavoy. Les Echinides des "Bagh Beds."
Part 2.—Mineral Production of India during 1917. Support of Mountains of Central Asia.
Part 3.—Structure and Stratigraphy in North-West Panjab. Aquamarine Mines of Daso, Baltistan. Srimangal Earthquake of July 8th, 1918.
Part 4.—Possible Occurrence of Petroleum in Jammu Province: Preliminary Note on the Nar-Budhan Dome, of Kotli Tehsil in the Punch Valley. Submerged Forests at Bombay. Infra-Trappoans and Silicified Lava from Hyderabad, S. India.

Vol. L, 1919.

Part 1.—General Report for 1918. Potash Salts of Punjab Salt Range and Kohat. Origin and History of Rock-salt Deposits of Punjab and Kohat.
Part 2.—Tungsten and Tin in Burma. Inclination of Thrust-plane between Siwalik and Murree zone near Koth, Jammu. Two New Fossil Localities in Garo Hills. Sanni Sulphur Mine. Miscellaneous Notes.
Part 3 (out of print).—Mineral Production of India during 1918. Gastropoda Fauna of Old Lake-beds in Upper Burma. Galena Deposits of North-Eastern Putao.
Part 4 (out of print).—Pitchblende, Monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. Natural Gas in Bituminous Salt from Kohat. Mineral Resources of Central Provinces. Miscellaneous Notes.

Vol. LI, 1920-21.

Part 1.—General Report for 1919. Pseudo-crystals of Graphite from Travancore. Mineral related to Xenotime from Manbhum District, Bihar and Orissa Province. Coal Seams of Foot Hills of the Arakan Yoma, between Lespan Yaw in Pakokku and Ngapè in Minbu, Upper Burma. Observations on "Physa Prinsepii," Sowerby and on a Chonid Sponge that burrowed in its shell.
Part 2.—Classification of fossil Cypræidæ. Sulphur near the confluence of the Greater Zab with the Tigris, Mesopotamia. Miscellaneous Notes.
Part 3.—Mineral Production of India during 1919. Results of a Revision of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma. Marine Fossils collected by Mr. Pinfold in the Garo Hills.
Part 4.—Illustrated comparative Diagnoses of Fossil Terebridæ from Burma. Indian Fossil Viviparæ. New fossil Unionid from the Intertrappean beds of Peninsular India. Unionidæ from the Miocene of Burma.

Vol. LII, 1921.

Quinquennial Review of Mineral Production of India for 1914-1918.

Vol. LIII, 1921.

Part 1.—General Report for 1920. Antimony deposit of Thabyu, Amherst district. Antimony deposits of Southern Shan States. Geology and Mineral Resources of Eastern Persia. Miscellaneous Notes.
Part 2.—Comparative Diagnoses of Pleurotomidæ from Tertiary Formation of Burma. Comparative Diagnoses of Conidæ and Cancellariidæ from Tertiary of Burma. Stratigraphy, Fossils and Geological Relationships of Lameta Beds of Jubbulpore. Rocks near Lameta Ghat (Jubbulpore District).
Part 3 (out of print).—Obituary: Frederick Richmond Mallet. Mineral Production of India during 1920. Mineral Resources of Bihar and Orissa.
Part 4.—Stratigraphy of the Singu-Yenangyat Area. Analysis of Singu Fauna. Sulphur Deposits of Southern Persia. A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica.

Vol. LIV, 1922.

Part 1.—General Report for 1921. Contributions to the Geology of the Province of Yünnan in Western China: VI.—Traverses between Tali Fu and Yunnan Fu. Geology of Takki Zam Valley, and Kaniguram-Makin Area, Waziristan. Geology of Thayetmyo and neighbourhood, including Padaukbin. Bitumen in Bombay Island.
Part 2.—Mineral Production of India during 1921. Iron Ores of Singhbhum and Orissa. Geological Results of Mount Everest Reconnaissance Expedition. Northern Extension of Wolfram-bearing Zone in Burma. Miscellaneous Note.

Part 3.—Obituary: Rupert William Palmer. Indian Tertiary Gastropoda. IV.—Olixidæ. Harpidæ, Marginellidæ, Volutidæ and Mitridæ, with comparative diagnoses of new species. Structure of Cuticle in Glossopteris angustifolia Brongn. Revision of some Fossil Balanomorph Barnacles from India and the East Indian Archipelago. Contributions to the Geology of the Province of Yünnan in Western China: 7.—Reconnaissance Surveys between Shunning Fu, Chingtung Ting and Tali Fu. 8.—Traverse down Yang-tze-chiang Valley from Chin-chaing-kai to Hui-li-Chou. Boulder Beds beneath Utatur State, Trichinopoly District. Miscellaneous Notes.

Part 4.—Geology of Western Jaipur. Geological Traverses from Assam to Myitkyina, through Hukong Valley; Myitkyina to Northern Putao; and Myitkyina to Chinese Frontier. Oligocene Echinoidea collected by Rao Bahadur S. Sethu Rama Rau in Burma. Mineral Resources of Kolhapur State. Kunghka and Manmaklang Iron Ore Deposits, Northern Shan States, Burma.

VOL. LV, 1923-24.

Part 1.—General Report for 1922. Indian Tertiary Gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ, Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species. Geological Interpretation of some Recent Geodetic Investigations (being a second Appendix to the Memoir on the structure of the Himalayas and of the Gangetic Plain as elucidated by Geodetic Observations in India).

Part 2.—Obituary: Ernest (Watson) Vredenburg. Fossil Molluscs from Oil-Measures of Dawns Hills, Tenasserim. Armoured Dinosaur from Lametta Beds of Jubbulpore. Fossil forms of Placuna. Phylogeny of some Turbinellidæ. Recent Falls of Aerolites in India. Geology of part of Khasi and Jaintia Hills, Assam.

Part 3.—Mineral Production of India during 1922. Lignitic Coal-fields in Karewa formation of Kashmir Valley. Basic and Ultra-Basic Members of the Charnockite Series in the Central Provinces. China Clay of Karalgi, Khanapur, Belgaum District.

Part 4.—Obituary: Henry Hubert Hayden. Oil Shales of Eastern Amherst, Burma, with a Sketch of Geology of Neighbourhood. Provisional list of Palæozoic and Mesozoic Fossils collected by Dr. Coggin Brown in Yunnan. Fall of three Meteoric Irons in Rajputana on 20th May 1921. Miscellaneous Note.

VOL. LVI, 1924-25.

Part 1.—General Report for 1923. Mineral Deposits of Burma.

Part 2.—Mineral Production of India during 1923. Soda rocks of Rajputana.

Part 3.—Gyrolite and Okenite from Bombay. Freshwater Fish from oil-measures of Dawns Hills. Fossil Ampullariid from Poonch, Kashmir. Calcareous Alga belonging to Triploporelleæ (Dasycladaceæ) from Tertiary of India. Froth Flotation of Indian Coals. Submarine Mud Eruptions off Arakan Coast, Burma. Cretaceous Fossils from Afghanistan and Khorasan.

Part 4.—Murua Meteorite. Stegodon Ganesa in Outer Siwaliks of Jammu. Land and Freshwater Fossil Molluscs from Karewas of Kashmir. Burmese Lignites from Namma, Lashio and Pauk. Maurypur Salt Works.

VOL. LVII, 1925.

Quinquennial Review of Mineral Production of India for 1919-1923. Price 5 Rs. 10 As.

VOL. LVIII, 1925-26.

Part 1.—General Report for 1924. Fossil Tree in Panchet Series of Lower Gondwanas near Asansol, with Palæontological Description.

Part 2.—Obituary: Francis William Walker. Possibilities of finding concealed coal-field at a workable depth in Bombay Presidency. Basaltic Lavas penetrated by deep boring for coal at Bhusawal, Bombay Presidency.

Part 3.—Mineral Production of India during 1924. Enstatite-Augite Series of Pyroxenes. Constitution of the Glauconite and Celadonite. Palagonite-bearing Dolerite from Nagpur.

Part 4.—Fossils Crétacés de l'Afghanistan. Fossiles du Kashmir et des Pamirs. Additions and Corrections to Vredenburg's Classification of the Cypræidæ. Petrology of Rocks from Girnar and Osham Hills, Kathiawar, India.

VOL. LIX, 1926.

Part 1.—General Report for 1925. Foraminifera of parts of Western India.

Part 2.—Sampling Operations in Pench Valley Coal-field. Composition of some Indian Garnets. Geology of Andaman and Nicobar Islands, with special reference to Middle Andaman Island. Occurrence of Cryptohalite. Remarks on Carter's Genus Conulites.

Part 3.—Mineral Production of India during 1925. Metamorphic Rocks and Intrusive Granite of Chhota Udepur State. Indian Species of Conoclypeus.

Part 4.—Low-Phosphorus Coking Coal in Giridih Coal-Field. Distribution of Gault in India. Age of so-called Danian Fauna from Tibet. Bauxite on Korlapat Hill, Kalahandi State, Bihar and Orissa.

VOL. LX, 1927-28.

Part 1.—General Report for 1926. Six Recent Indian Aërolites.

Part 2.—Gas Eruption on Ramri Island, off Aracan Coast of Burma, in July, 1926. Oil Indications at Drigh Road near Karachi. Lower Canine of Tetraconodon. Geology of Bundi State, Rajputana.

Part 3.—Mineral Production of India during 1926. Geological Traverse in Yunaslin Valley. Ambala Boring of 1926-27. Indian Unionidæ.

Part 4.—Relationship between Specific Gravity and Ash Contents of Coals of Korea and Bokaro Coals as Colloid Systems. Contact of Basalt with coal-seam in the Isle of Skye, Scotland. Comparison with Indian examples. Barakar-Ironstone Boundary near Begunia, Raniganj Coal-Field. Raniganj-Panchet Boundary near Asansol, Raniganj Coal-Field. Permo-Carboniferous Marine Fauna from Umaria Coal-field. Geology of Umaria Coal-field, Rewah State, Central India. Composition and Nomenclature of Chlorophæite and Palagonite, and on Chlorophæite Series. Miscellaneous Notes.

VOL. LXI, 1928-29.

Part 1.—General Report for 1927. Actionodon risinensis in Lower Gondwanas of Vihi district, Kashmir. Miscellaneous Note: Further Note on Nomenclature of Hollandite.

Part 2.—Contribution to Geology of Punjab Salt Range. Iron Ore Deposits of Northern Shan States. Lower Canine of Indian Species of Conohyus. Miscellaneous Note: Leucopyrite from Kodarma.

Part 3.—Mineral Production of India during 1927. Note on Coking Tests with Gondwana Coals. Zinc-Spinel from Southern India. New Indian Meteorite: Lua Fall. Miscellaneous Note: Löllingite from Hazaribagh District.

Part 4.—Erratics of the Punjab. Cretaceous Dinosaurs of Trichinopoly District, and Rocks associated with them. Orbitolinæ from Tibet. Joya Mair Dome Fold, near Chakwal, Jhelum District, Punjab. Occurrence of Allophane at Tikak, Assam. Miscellaneous Note, Australian Species of Genus *Gisortia*.

VOL. LXII, 1929-30.

Part 1.—General Report for 1928. Miscellaneous Note: New Chromite Localities.

Part 2.—Obituary: Sivarau Sethu Rama Rau. Specific Gravity and Proximate Composition of Indian Vitrains. New Devonian Fossils from Burma. Rangoon Earthquakes of September and December 1927. Epicentre of North-West Himalayan Earthquake of 1st February 1929. Miscellaneous Notes: Indian Beryl. Atacamite in Bihar and Pyromorphite in Bhagalpur district, Bihar.

Part 3.—Mineral Production of India during 1928. Granophyric Trachite from Salsette Island, Bombay. Coal Resources of Jharia Coalfield. Coal lost by Fires and Collapses in Indian Coal Mines.

Part 4.—Age of Aravalli Range. Lake's Rule for Angle of Overthrust, as applied to Himalayas. Permo-Carboniferous Succession in Warcha Valley, Western Salt Range, Punjab. Naoki (Hyderabad) Meteoric Shower of 29th September 1928. Miscellaneous Notes: Boring for water at Daryapur and Fossil Eggs at Yenangyaung.

VOL. LXIII, 1930.

Part 1.—General Report for 1929. Upper Triassic Fossils from Burmo-Siamese Frontier.—Thaungyin Trias and Description of Corals. Upper Triassic Fossils from Burmo-Siamese Frontier.—Brachiopoda and Lamellibranchia from Thaungyin River. Upper Triassic Fossils from Burmo-Siamese Frontier.—Fossils from Kamawkala Limestone. Upper Triassic Fossils from Burmo-Siamese Frontier.—New Dasycladaceæ, *Holosporella siamensis* nov. gen., nov. sp., with Description of Allied Genus *Aciculella* Pia. Cretaceous Cephalopods in 'Red Beds' of Kalaw, Southern Shan States, Burma.

Part 2.—Methods of Analysis of Coal used at Government Test House, Alipore, Calcutta, with an Editorial Introduction. New fossil localities within Panchet series of Raniganj Coalfield. Species of *Cyllene* from Pegu Beds of Burma. Two new species of *Unio*. Glaciers of Karakoram and Neighbourhood. Miscellaneous Note: Dome near Mari in Attock District.

Part 3.—Mineral Production of India during 1929. On the Specific Gravity and Proximate Composition of some Indian Durains.

Part 4.—Aspects of Modern Oil Field Practice. Undescribed freshwater Molluscs from various parts of India and Burma. Second note on North-West Himalayan Earthquake of 1st February, 1929. Miscellaneous Notes: Tremolite from near Jasidih, Bihar, Sapphirine in Vizagapatam District and Titaniferous Augite from Chandrawati, Sirohi State, Rajputana.

VOL. LXIV, 1930.

Quinquennial Review of Mineral Production of India for 1924-1928. Price 9 Rs. 6 As.

VOL. LXV, 1931-32.

Part 1.—General Report for 1930. Additional Note on Samelia Meteorite. Zoning and Difference in Composition of Twinned Plagioclase Felspars in certain rocks from Sirohi State, Rajputana. Albite-Ala B Twinning of Plagioclase Felspars in certain acidic rocks from Sirohi State, Rajputana. Jurassic Fossils from Northern Shan States.

Part 2.—Syntaxis of North-West Himalayas: Its Rocks, Tectonics and Orogeny. Preliminary Note on Pegu Earthquake of May 5th, 1930. Determination from World Records of Zero-time and Epicentre of Pegu Earthquake of May 5th, 1930. Long Distance Wave Speeds of Pegu Earthquake of May 5th, 1930. Rocks bearing Kyanite and Sillimanite in Bhandara District, C. P. Stratigraphy of Upper Ranikot Series (Lower Eocene) of Sind, India. Miscellaneous Note: Fuchsite Vase from Mohenjo Daro (Sind).

Part 3.—Mineral Production of India during 1930. Geology and Lead-ore Deposits of Mawson, Federated Shan States. Weathering of Vindhyan Building Stone. *Maclurites* from Ordovician of Burma. Miscellaneous Notes: Supplementary note on "Revisions of Indian Fossil Plants, Part II Coniferales (*b.* Petrifactions), 1931" and Eruption of Mud Volcano off Arakan Coast.

Part 4.—Reaction Minerals in Garnet-Cordierite-Gneiss from Mogok. Vindhyans of western Rajputana. Granitic Intrusions in Ranchi and Singhbhum Districts. Miscellaneous Notes: *Chonetes* in Krol Limestone; Green Mica from Bhandara District; and Olivine-Basalt and Tuffs in Malani Series at Jodhpur.

VOL. LXVI, 1932-33.

Part 1.—General Report for 1931. Rudistæ from Eastern Persia.

Part 2.—Lower Palæozoic Fossils from the Southern Shan States. Geology of Nanga Parbat (Mt. Diamir) and adjoining portions of Chilas, Gilgit District, Kashmir. Fossil Plants from Parsora Stage, Rewa. Swa Earthquake of August 5th, 1929. Overlap in the Ngape Area, Minbu District. Miscellaneous Note: Ammonite from Ramri Island.

Part 3.—Mineral Production of India during 1931. Microscopic Study of some Indian Coals. Specific Gravity and Porosity of Indian Building Stones. Indian Seismological Records of Chief Shocks in N.-E. Frontier Region of Burma during 1929 and 1930. Glacier in Arwa Valley, Garhwal.

Part 4.—Stratigraphic significance of Fusulinids of Lower Productus Limestone of Salt Range. *Dadoxylon Zalesskyi*, a new Species of Cordaitean trees from Lower Gondwanas of India. Fossil Pentalocular Fruit from Pondicherry. Kalava (Calwa) 'Wall' in Kurnool District. Talc-Serpentine-Chlorite Rocks of Southern Mewar and Dungarpur. Age of certain Himalayan Granites. Tables of Production, Imports, Exports and Consumption of Minerals and Metals in India.

VOL. LXVII, 1933-34.

Part 1.—General Report for 1932. Anthracolithic Faunas of Southern Shan States.

Part 2.—Geological Reconnaissance in Southern Shan States. Geology of the country between Kalaw and Taunggyi Southern Shan States.

Part 3.—Mineral Production of India during 1932. Geological Notes on Traverses in Tibet made by Sir Henry Hayden in 1922. Origin of Streaky Gneisses of Nagpur District.

Part 4.—Geology of the Krol Belt. Crush Conglomerates of Dharwar Age from Chota Nagpur and Jubbulpore.

VOL. LXVIII, 1934-35.

Part 1.—General Report for 1933. Obituary: Malhari Vinayak Rao. Khanpur Meteoric Shower. Cambrian Sequence of Punjab Salt Range.

Part 2.—Cambrian-Trias Sequence of North Western Kashmir (Parts of Muzaffarabad and Baramula Districts). Preliminary account of Earthquake of 15th January, 1934, in Bihar and Nepal. Obituary: Pramatha Nath Bose. Miscellaneous Notes: Barytes in Manbhum District, Bihar; Soda Deposit and Manufacture of Caustic Soda and Crude Soap at Parantij, Ahmedabad District; Potash content of *Reshta*, Sambhar Salt Lake, Rajputana; Alunogen from Cuddapah District; and Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1934.

Part 3.—Mineral Production of India during 1933. Manganese-Lime Series of Garnets. Chemical Composition of Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1934.

Part 4.—Soils of India. Lateritisation of Khondalite. Snout of Biafo Glacier in Baltistan. Turonian Ammonite (*Mammites Daviesi*) from Ramri Island, Burma. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1934; Tertiary Rocks near Puri; and Cretaceous and Eocene Volcanic Rocks of the Great Himalaya Range in North Kashmir.

VOL. LXIX, 1935-36.

Part 1.—General Report for 1934. Primitive Fossils, possibly Atrematous and Neotrematous Brachiopods, from the Vindhyans of India. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1934, and Additional Note on Nomenclature of Hollandite.

Part 2.—Traverses in Himalaya. Jabalpur Plants from Satpura-Gondwana Basin. *Rhizomopsis* Gothan and Sze and *Dictyopteridium* Feistmantel. Sphærosiderite, containing a New Species of *Dadoxylon* (*D. parbeliense*), from Lower Gondwana Coal Measures of India. Earthquakes recorded by the Pendulum Seismograph at Shillong (Assam) from 1903 to 1931. Preliminary Geological Report on Baluchistan (Quetta) Earthquake of May 31st, 1935. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1935 and Gypsum in Upper Vindhyans of Rajputana.

Part 3.—Mineral Production of India during 1934. India's Coal Resources. (Being a note on the reserves available in India of good quality coal including coking coal). Results of Low-Temperature Carbonisation of some Lower Gondwana Indian Coals. Attrition tests on Stones used as Road-Metal in India. Obituary: James Malcolm Maclaren. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1935.

Part 4.—Buchanan's Laterite of Malabar and Kanara. Solubility of Quartz. Natural Gas at Gogha, Kathiawar. Patwar Meteoric Shower of the 29th July, 1935. *Fermoria minima*: A Revised Classification of Organic Remains from Vindhyans of India. Ore minerals from Bawdwin, Shan States. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1935.

VOL. LXX, 1936.

Quinquennial Review of Mineral Production of India for 1929-1933. Price 6 Rs. 4 As.

VOL. 71, 1936-37.

Part 1.—General Report for 1935. Dyke Rocks of Keonjhar State, Bihar and Orissa. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1935.

Part 2.—Perpeti Meteoric Shower of 14th May, 1935. Tirupati and Babjoi Meteorites. *Ostrea (Crassostrea) gajensis* from near Baripada, Mayurbhanj State. *Matonidium* and *Weichselia* in India. Cretaceous Cephalopods from Red Beds of Kalaw and Age of Red Beds. Contributions to the Geology of the Province of Yünnan in Western China: 9.—Brachiopod Beds of Liu-wun and related formations in Shan States and Indo-China. Geological Age of Namyau, Liu-wun and Napeng Beds and of certain other formations in Indo-China. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1936.

Part 3.—Mineral Production of India during 1935. Marble of the North-West Frontier Province. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1936.

Part 4.—Obituary: Richard Dixon Oldham. Geology of Second Defile of Irrawaddy River. *Orbitolina*-bearing rocks in Burma: with description of *Orbitolina birmanica*, sp. nov. Rocks in vicinity of Kyaukse. Burma. Mesozoic coniferous wood (*Mesembrioxylon shanense*, sp. nov.) from Southern Shan States of Burma. Foraminifera from Intertrappean Beds near Rajahmundry. *Holosporella* cf. H. *Siamensis* *Pia*, from Rajahmundry Limestones. Maleri beds of Hyderabad State (Deccan) and Tiki Beds of South Rewa. Structure of Himalaya in Garhwal. Miscellaneous Notes: Coaly Shale in Deccan Trap in Indore, Central India. Octahedral Pyrite Crystals from Kohat District, North-West Frontier Province. Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1936.

VOL. 72, 1937.

Part 1.—General Report for 1936. Note on 'coalite'. Freshwater and Land Fossil Molluscs from near Ghorband, Afghanistan. Provisional statistics of some of the more important Indian Minerals for 1936. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1936.

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VOL. 73, 1938.

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RECORDS

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ARE THE EQUIDAE RELIABLE FOR THE CORRELATION OF THE SIWALIKS WITH THE COENOZOIC STAGES OF NORTH AMERICA? BY GUY E. PILGRIM, D.SC., F.G.S., WITH AN APPENDIX BY A. T. HOPWOOD, D.SC., F.L.S.

During the last decade views have become prevalent in America on the correlation of the various Siwalik stages with the mammal horizons of Europe and North America, which are wholly at variance with those which I have expressed since 1913 and which with a few modifications I still hold. These modifications may be seen if my paper of 1913 be compared with the correlation which I published in 1934 and are more succinctly expressed in a diagram published by Lewis in 1937 (p. 194). A further modification will be necessitated if De Terra's and Teilhard's work in India, involving the shifting of the Siwalik Boulder Conglomerate from the Lower into the Middle Pleistocene, can be substantiated.

These American views were first published in a paper by Matthew in 1929. They were reiterated and somewhat elaborated by Colbert in a short paper of 1935 and again in a larger work (1935, pp. 21-27). During 1936 De Terra published brief accounts of the work of an expedition sent by Yale University to Kashmir and north west India, and a fuller account of that portion of it which bears on the correlation of the Upper Siwalik and Later Pleistocene was published in 1936 under the associated names of De Terra and Teilhard de Chardin. Still later, Lewis (1937, pp. 191-204) published a correlation of the Siwaliks based partly on his own work and partly on that of

the De Terra expedition. In certain respects this differs less than that of Matthew and Colbert from my own correlation, but it is still based, as in their case, on the first appearance of the genera *Hipparion* and *Equus* in North America, which all these authorities regard as their earliest appearance anywhere in the world and as affording evidence of age which is irrefutible.

I have already briefly set forth some arguments in support of my own view and have suggested that a dual origin for *Hipparion* would explain the inconsistency which Colbert has so well indicated. Teilhard and Stirton (1934, p. 282) have also indicated their opinion that such a phenomenon might be possible, and their correlation of the Chinji and Dhok Pathan almost follows my own. The position to which they assign the Val D'Arno and Perrier faunas, in the Astian rather than the Villafranchian is, however, not easy to understand. As remarked above, the first author appears to have altered his opinion since his visit to India.

In view of the accumulation during the last few years of fresh facts which concern the Bovidae and which have only just been published, and on account of the scattered nature of certain faunal evidence which has caused it to escape the notice of at any rate some of my critics, I think it will be advantageous to review the whole question again in much greater detail.

A knowledge of the distribution of the fossil species throughout the various Siwalik stages is essential to the understanding of the evidence by which one must be guided in any attempt to correlate the faunas with those of other parts of the world. For this purpose Colbert's excellent faunal lists (1935, pp. 29-36) will serve for all the groups except the Bovidae, which was in the course of revision when Colbert's paper was written. The table of the geological distribution of the fossil Bovidae in India, which occupies pages 5-7 of my 1939 memoir on the Fossil Bovidae of India will supply the omission.

I propose first to criticize De Terra's and Lewis' papers mentioned above and afterwards to consider how far Matthew's and Colbert's theory fits the facts. This theory, so far as I can gather, is accepted in a greater or less degree by the other three authors.

The most important results of De Terra's work, so far as it affects the correlation of the Siwaliks are:

1. The recognition of a complete glacial cycle in Kashmir, which corresponds closely to what is found in Europe.

2. The correlation of the Karewa beds, in which he has found fossils, with the events of this cycle.

3. The identification of the Siwalik Boulder Conglomerate with the second glacial period, and the existence of a great unconformity between the Siwalik Boulder Conglomerate and the Pinjor stage.

In connection with the third of these, De Terra's sections in figures 7 and 8, page 804, near Jammu and along the Tawi river are crucial to his case. One would feel more satisfied about the correctness of his identification of these and other horizontally bedded exposures of boulder conglomerate with the well-known Boulder Conglomerate of the Siwaliks if they contained determinable fossils. Unfortunately this appears not be the case. Fossils have, however, been found in the Siwalik Boulder Conglomerate in the Siwalik Hills by the Geological Survey of India as well as by Dr. Barnum Brown, so that we may hope that this lack may be supplied later. Conglomerates in India are, however, notoriously difficult to identify and one cannot but be struck by the fact that, as the Geological Survey of India have established, throughout the whole Sub-Himalayan region from Jammu to Nepal the Boulder Conglomerate shares completely in the folding which has affected the underlying Pinjor beds and no unconformity is observable. At the same time one cannot deny that there is the possibility of an overlap of the Boulder Conglomerate on to the lower beds of the Siwaliks, when we get away from the hills, and one is bound to accept provisionally the lithological resemblance on which De Terra relies. It seems, however, unwise to adopt the designation of Tawi stage for the Boulder Conglomerate, as Lewis suggests, so long as there remains any room for doubt that in the Tawi section we actually have to do with the true Siwalik Boulder Conglomerate.

De Terra's correlation of the Kashmir deposits appears to be based on the assumption that the glacial cycle began in the world generally with the advent of the Pleistocene. When, therefore, his observations proved to his satisfaction that the Boulder Conglomerate coincided with the second ice advance, it became evident that on the glacial chronology which he has accepted the Boulder Conglomerate must be middle Pleistocene. So far, if we are willing to admit that he was right in identifying the boulder conglomerate in contact with a ground moraine of the second stage with the

Siwalik Boulder Conglomerate, there seems no escape from his conclusion. Where he seems to go beyond his facts is in assuming that the remainder of the Upper Siwalik, namely the Tatrot and Pinjor stages must correspond to the first ice advance and the first interglacial stage, and must accordingly be classed as Lower Pleistocene. This does not follow. Since his observations show, again on the assumption that his interpretation of the Tawi section is correct, that there is an enormous erosion unconformity between the Siwalik Boulder Conglomerate and the underlying Siwalik stages, it is obviously not merely possible but likely that the Lower Pleistocene is represented by a break in deposition in India itself and that the Pinjor stage corresponds with the Upper Pliocene (Villafranchian) of Europe. How far this is consistent with the discovery by Dr. Barnum Brown of *Bubalus platyceros* from the top of the Siwalik Boulder Conglomerate one-half mile west of Siswan, Siwalik Hills, is another question. Other instances of typical Pinjor species occurring in the Boulder Conglomerate would certainly militate against the identification of the Tawi conglomerate which I have provisionally accepted.

On the Kashmir plateau itself De Terra appears to be convinced (1936, p. 686) that the Lower Karewas correspond to the first glacial period and are undoubtedly Lower Pleistocene. He infers that the fauna found in these beds justifies a correlation with the Pinjor stage. The only fossils, so far as I am aware, which he has recorded from the Lower Karewas are *Equus*, *Elephas namadicus*, *Bos*, *Sus*, *Rhinoceros*, *Cervus*, *Felis*, *Sivatherium*. Of these *Elephas namadicus* is undoubtedly post-Pinjor and is abundant in the older Narbada Alluvium, while it is not impossible that *Sivatherium* should have persisted beyond the Pinjor stage. Moreover, De Terra has found no evidences of glacial action in the Pinjor any more than there are in the Val d'Arno or Perrier, so that a correlation of the Pinjor stage with the Upper Pliocene (Villafranchian) of Europe, more in harmony with the character of its fauna and its stratigraphic and faunistic relations to the stages of Tatrot and Dhok Pathan, is more probable than De Terra's rather forced correlation with the Lower Karewas. A comparison of the Pinjor fauna with those of the Val d'Arno, Perrier and Senèze is discussed later in this paper.

To such authorities as Hopwood (1935, p. 46), with whom Lewis agrees, the advent of *Equus*, *Elephas* and *Bos* marks the beginning of the Pleistocene. Consequently both Pinjor and Val d'Arno

are Pleistocene, and each one of De Terra's glacial stages must be shifted to a later period. Colbert hardly goes as far as this, although the position in which he places the Val d'Arno on the boundary between Pliocene and Pleistocene would imply some disposition to adopt Hopwood's view. I doubt whether De Terra realizes the full implications of the correlation which he has adopted.

Hopwood's inclination to choose the advent of a few important invading types as marking the beginning of each main period is very attractive in the absence of geological evidence. In order that this criterion should be valid throughout the area of distribution of such types he assumes that the migration of any form is practically instantaneous. So far as actual travel is concerned, I quite agree with him that there is no reason to suppose that a species should take long to move from one area into another, but it seems obvious that physical or climatic conditions might alter the case. The Pontian fauna of Europe offers a classic example of a fauna which we have every reason to believe existed in Asia and America for at least a stage before it penetrated into Europe, its arrival into the latter continent being marvellously sudden. It follows that Hopwood's correlation test can only be rigidly applied in a single region, like Europe which has been thoroughly explored. It is liable to fail when an attempt is made to extend its application elsewhere, since we cannot be sure that the form in question invaded other parts of the world simultaneously with its invasion of Europe to say nothing of the area in which it originated, very probably an unknown one and to which for some reason or other it may have been confined for a considerable time. Further, more intensive collecting in any particular region may alter the opinion which we first formed as to the arrival or origin of a genus. A very apposite example of this is to hand in the case of the occurrence of the genera *Equus* and *Elephas* in India. Originally regarded as making their first appearance in the Pinjor stage, this seemed to afford an extremely sound reason for correlating the Pinjor with the Villafranchian of Europe in the Lower Pleistocene. Now it appears that both genera also occur in the Tatrot stage, but it is quite unreasonable to consider the Tatrot as equivalent to the Villafranchian and so Lower Pleistocene, in defiance of the remainder of the fauna.

It is not of great concern to me here as to whether it is considered more appropriate to place the deposits of the Val d'Arno, Senèze

and the Red Crag into the Pliocene or Pleistocene, or those of Pikermi and Samos into the Miocene or Pliocene. On the other hand, it is obviously of great importance from a zoological point of view that the Siwalik stages should be correlated with the mammaliferous stages of Europe with as great an approach to accuracy as possible. For this reason it is a pity that certain authors, in assigning an age to the Siwalik stages, should prejudge the question and use the terms Miocene, Pliocene and Pleistocene, thus leaving it doubtful with which stage they think that the Indian beds they may be discussing correspond.

Lewis' correlation is in large part a compromise between De Terra's, Colbert's and my own. He agrees with Hopwood that the appearance of *Equus* should mark the beginning of Pleistocene time. At the same time he considers that the onset of glacial conditions should equally mark it. These two standards, as far as we know at present, are incompatible. *Equus* appears in the Val d'Arno and Perrier, but there is, so far as I am aware, no indication of glaciation. *Equus* is also pre-glacial in certain Texas deposits. Like De Terra, Lewis places the Tatrot and Pinjor stages into the Lower Pleistocene. While De Terra and Teilhard have merely confessed to an inability to distinguish the Tatrot and Pinjor stages, though admitting the possibility of separating them if more was known about the Tatrot fauna, Lewis has definitely united them into a single stage with the name of Tatrot. Both Lewis and De Terra seem to have been led to consider the Tatrot and Pinjor faunas as one and the same, by their wish to minimize the fact that the Pinjor fauna corresponds so well with that of the Villafranchian of Europe that it is difficult to regard it as belonging to the later Cromerian or Sicilian stage. By assuming that the whole of the Pinjor fauna is spread through the Upper Siwaliks the situation is rendered somewhat easier. De Terra places the Dhok Pathan stage into the Upper Pliocene, whereas Lewis correlates the Dhok Pathan with the stage of Roussillon as Middle Pliocene, assuming that there was a long break between the Dhok Pathan and Tatrot corresponding to which there is no vertebrate fauna known in India. The Nagri stage becomes the equivalent of the Pontian, the Chinji of the deposits of Sebastopol, and the Kamlial of the combined La Grive Saint Alban and Sansan stages.

Lewis' statement as to the existence of a great unconformity between the Dhok Pathan and the Tatrot stages, makes no reference

to the fact, of which he was probably unaware, that I had previously (1913, pp. 274-277) stressed this very strongly. I was not, however, disposed to regard the break as universal even in the Salt Range area, and perhaps nowhere as of such long duration as Lewis thinks. Not only do the faunas of the two stages which are discussed below militate against the long time interval which Lewis predicates, but also the concordance of dip which, so far as I am aware, everywhere exists between them. On the contrary Lewis has represented a very small break between the Pinjor stage and the Boulder Conglomerate, to which he has given the name Tawi stage. This is quite inconsistent if he accepts De Terra's interpretation of the Tawi section, where the Boulder Conglomerate is shown resting on the highly tilted denuded edges of the Pinjor strata. The remarkable change in the character of the rocks tells equally in the same direction, while the known fauna of the Boulder Conglomerate and the older Narbada Alluvium presents no features which can be held to be opposed to De Terra's correlation of the two.

A still more revolutionary idea is propounded by Lewis, when he places the deposits of Roussillon and Montpellier into the Plaisancian and leaves the entire Astian stage without any vertebrate fauna in Europe. The assumed absence of Astian land deposits in Europe is evidently intended by Lewis to correspond with the long interval which in India he assumed to have elapsed between the Dhok Pathan, *ex hypothesi* the equivalent of Roussillon, and the Tatrot, *ex hypothesi* the equivalent of the Villafranchian.

I think it may perhaps be advantageous briefly to summarize the arguments against removing Roussillon so far in time from Perrier and Senèze, not because Depéret's classic studies, which have been accepted in Europe for the last fifty years need any support from me, but because the arguments employed may be applicable in estimating the degree of affinity between the Tatrot and the Dhok Pathan on the one hand and the Pinjor on the other. The evidence of certain recent determinations, unknown to Depéret, may also not be without some value.

The character of the European fauna altered considerably between the Pontian and the stage of Roussillon. Numerous families and genera have disappeared. *Dinotherium*, *Mastodon* (*Trilophodon*), *Mastodon* (*Tetralophodon*) of the type of *T. longirostris*, Chalicotheriidæ, *Aceratherium*, *Chilotherium*, Tragulidæ, Giraffidæ, *Listriodon*.

the large pigs of the *Microstonyx* type, Hippotraginae, Tragelaphinæ, *Tragocerus*, *Criotherium*, *Amphicyon*, *Ursavus*, *Indarctos*, *Sivaonyx*, *Enhydriodon*, *Promeles*, *Promephitis*, *Ictitherium*, Hyænidae of the type of *Crocuta eximia*, *Machairodus*, *Paramachaerodus*, *Steneofiber*, and *Dryopithecus* are among the chief of these.

There are very few surviving genera from the Pontian, and almost all of these differ specifically. *Hipparion crassum* is markedly different not only from *H. gracile* but also from *H. mediterraneum* and other Pontian species. *Parabos cordieri* and *P. boodon* have been referred to the same genus as *Parabos* (?) *macedoniae* from Salonika, but the material of the latter is hardly sufficient for comparison. *Epimachairodus tarakliensis* is probably ancestral to *E. crenatidens*, which abounds in the Villafranchian, but has also been identified by Schaub from Roussillon. *Tapirus* persists, but only as the different species, *T. arvernensis*. *Hystrix primigenius* is found both at Pikermi and Roussillon. *Cricetus kormosi* from the Pontian of Polgardi may be regarded as ancestral to *C. angustidens* of Perpignan. *Mus gaudryi* is not closely related to *Mus donnezani*. Orycteropus depéreti from Roussillon is much larger than the Pontian O. gaudryi and differs from it in other ways. *Meles gennevauxi* and *Plesiogulo monspessulanus* (see Viret 1939) are Asiatic migrants, the former related to *Meles taxipater* and the latter to *Plesiogulo brachygnathus* but of a more progressive type approaching *Gulo*. *Meles taxipater* is a Chinese Pontian form and *Plesiogulo brachygnathus* is found both in the Pontian of China and the Dhok Pathan of India.

On the other hand numerous species from Roussillon are identical or nearly so with Villafranchian forms. Such are : *Hyæna arvernensis*, *Felis brevirostris*, *Megantereon megantereon*, *Epimachairodus crenatidens*, *Mastodon* (*Anancus*) *arvernensis*, *Tapirus arvernensis*, *Dicerorhinus leptorhinus* of Roussillon occurs at Perrier. In the Val d'Arno it is replaced by *D. etruscus*. *Cervus ramosus* occurs at both horizons. A species of *Gazella* from Perpignan has been referred to *G. borbonica* from Perrier (Roccaneyra) and the Red Crag.

Types which make their first appéarance in Europe at Roussillon are : Alopecoid Canidæ, as *Vulpes donnezani* represented in the Villafranchian by the different species *Canis megamastoides* ; *Ursus*, as a variety *ruscinensis* of the wide spread Villafranchian species *U.* (*Helarctos*) *arvernensis* ; *Cervus* (*Capreolus*) is known by the species *C. australis* which is closely allied to *C. cusanus* from Perrier ; *Potamochoerus*, as *P. provincialis*, of which a variety, *minor* occurs both

at Roussillon and at Perrier (Roccaneyra); the Ctenodactylidæ as *Ruscinomys*; *Trogontherium* as a variety *minus* of the wide spread Villafranchian *T. cuvieri*. *Castor* as the species *C. praefiber*, which does not differ except in size from the later *C. fiber*; *Agriotherium* replaces *Indarctos* of the Pontian and is represented by *A. insigne* of Montpellier and *A. sp.* Flower recorded by Newton from the Red Crag. Although *Hipparion* does not generally occur in the Villafranchian, yet it has been recorded by Stehlin from Perrier (Roccaneyra). Besides the Ctenodactyl *Ruscinomys* and the Macacine primate *Dolichopithecus*, the only genera which do not persist into the Villafranchian are *Parabos* and *Viverra*, of which the last European representative occurs at Roussillon as *V. pepratxi*.

Numerous species of *Gazella* and *Crocuta* occur in the Villafranchian which have not been found at Roussillon, as well as *Mastodon* (*Zygolophodon*) *borsoni*. The absence of all of these from the Astian fauna of Europe especially of the last may be accidental. An ancestral form of *Mastodon* (*Zygolophodon*) *borsoni* occurs in the Pontian as *M.* (*Zygolophodon*) *turicensis*.

The differences which the fauna of the Villafranchian displays from that of Roussillon are mainly due to what are invading forms, which does not necessarily imply any great difference in age. This part of the fauna includes *Equus*, *Elephas planifrons* and *E. meridionalis*, *Pannonictis*, *Sus strozzii*, numerous Caprine lineages such as *Deperetia*, *Procamptocerus*, *Megalovis*, *Nemorhædus*, the spiral-horned Gazelline, *Gazellospira torticornis*, and *Leptobos*.

When we observe that the comparable forms are either specifically the same or differ very little from one another, we are forced to conclude that little development took place between the two levels. Very little of the Roussillon and Montpellier fauna became extinct between that stage and that of the Val d'Arno, Perrier and Senèze, as compared with the multitude of families and genera which appear for the last time in the Pontian. I can see no grounds for regarding the two faunas as very different in age, while on the contrary a great zoological gap is suggested between Roussillon and the Pontian. Two littoral or marine stages, the Plaisancian and the Astian, intervene between the Villafranchian and the stage which corresponds to the mammaliferous lignites of Casino. The fauna of the Casino lignites is perhaps slightly younger than that of the Pontian. Depéret, therefore, most reasonably considered that the Roussillon fauna corresponded with the Astian, while the Plaisancian

filled the faunal gap between the Pontian and Roussillon faunas. There is no mammal fauna known in Europe which can be said to correspond with certainty to the Plaisancian. Besides the Casino fauna, Depéret suggested that the Baroth Kopecz lignites of Hungary and those of Alcoy in Spain might belong to this period. Depéret's conclusions as to the general faunal succession have never been seriously disputed, and Lewis has advanced no arguments for overthrowing the view generally held.

To return to India, it will be convenient if as a preliminary to a discussion of the main correlation I bring forward certain arguments based on the fuller examination of the Tatrot fauna, of which Lewis, De Terra and Teilhard were unaware when they expressed the above views. I hope these will show at any rate the utility, if not the absolute necessity, of dividing the Upper Siwaliks below the Boulder Conglomerate into two faunal stages. Originally (Pilgrim, 1913, pp. 276, 321-323) I based my separation of the Tatrot from the Pinjor on two main considerations:

1. The apparent absence of *Equus* and *Elephas* from the Tatrot.
2. The assumption that certain species which abounded at Tatrot but had not been rediscovered in the Siwalik Hills since the time of Falconer, belonged to a deposit which was older than that to which the bulk of the Siwalik Hills fossils were obtained. Examples of these are *Hipparion*, *Hippohyus*, and *Mastodon* (*Pentalophodon*) *sivalensis*. This assumption was based on the fact that in more than one place on the plains side of the Siwalik Hills there exist deposits which are not only lower than the Pinjor beds but also differ in their lithology. The best known of these is that in the Kalawala Rau from which Falconer (1868, pp. 33-36) obtained numerous fossils; I have myself found *Hipparion* in the same spot. Regarding Falconer's collection it is unknown whether it still exists or has become mixed up with those of the Pinjor stage. The beds lie east of the area which Colbert has reproduced in his sketch map of the neighbourhood of Moginand (Colbert, text figure 25, p. 49). Reference has already been made (Pilgrim, 1919, p. 193; 1932, p. 3) to the possibility of their being a representative of the Tatrot stage.

The discovery of *Equus* at Tatrot, and of a primitive species of *Elephas* (*Archidiscodon*) cf. *planifrons* by Lewis disposes of the first of these arguments. The second though not actually proved to be wrong is still invested with some doubt, because with the exception of *Merycopotamus*, none of the suspected species has yet been rediscovered in the Siwalik Hills, while Osborn has erected for the Tatrot *Mastodon* a new species, *Pentalophodon falconeri*, distinct from that of the Siwalik Hills. There are, however, other important differences in the known faunas of the Tatrot and the Pinjor, which seem amply to support my contention that these two stages are faunistically distinct. These were for the most part unknown to Lewis, as he had only my provisional and incomplete list of species (Pilgrim, 1913, p. 322) before him, the corrections and additions to it being scattered through publications dealing with special groups, or in the case of the Bovidae in an unpublished memoir (*Pal. Ind.* N. S. XXVI, 1939). Even now I regret that I have not had recent access to the original collections made by Vinayak Rao and myself on the Tatrot plateau. They are in any case not rich in species, though intensive collection at Tatrot, Kotal Kund and Bhaun would probably add considerably to the number of these.

I should first like to comment on the occurrence of *Hipparion* at Tatrot, which both De Terra and Teilhard as well as Lewis have stated to occur as rolled fragments derived from the Dhok Pathan, and regard as important. The presence of rolled *Hipparion* at Tatrot does not in the least affect the certainty that *Hipparion* must have lived at the Tatrot period, since numerous specimens of it from the Siwalik Hills exist in the British Museum (Lydekker, 1885, pp. 59-64), which even if they did not come from the Pinjor stage (a supposition which is unlikely since the character of the matrix agrees with that of the bulk of the fossils from that stage), yet cannot belong to an earlier horizon than that of Tatrot, since Dhok Pathan beds are not exposed in that area. Consequently the occurrence of rolled fragments of *Hipparion* in the basal conglomerate of Tatrot, however interesting, is without significance in connection with the question of the correlation of the Tatrot fauna.

Following the principles which have determined the separation of the European faunas of Roussillon from that of the Val d'Arno, Perrier and Senèze, I will now state some of the reasons which, in my opinion, justify the faunal separation of the Tatrot and Pinjor

stages. Quite a fair proportion both of species as well as genera pass up from the Dhok Pathan into the Tatrot. The list given below would probably be much greater if the Tatrot fauna were richer. Unfortunately, too, we have no assurance that some of the specimens obtained at Hasnot by the early geologists did not come out of Tatrot beds. In those days the accumulation of fossils in the basal beds of the Tatrot stage must have been much greater than is the case to-day, and it may be taken as certain not only that they ran more risk of being washed down on to Dhok Pathan outcrops, but also villagers who brought fossils to the geologists cannot have failed to visit the Tatrot cliffs, since they lie little more than two miles from Hasnot. In such cases the locality label attached to the specimen would be misleading, and our only clue to the horizon is the character of the matrix which is wholly different in the case of the two deposits. Where the matrix has been removed, this indication is lacking. Even, however, if we disregard the possibility that the Tatrot fauna is richer in such specimens than the actual list of species would lead us to imagine, yet there remain some which we definitely know to have been collected from the Upper Siwaliks of Tatrot, Kotal Kund or Bhaun which cannot be separated specifically from those of the underlying Dhok Pathan stage, but which do not persist into the Pinjor stage, except in the case of *Merycopotamus*. These are :

Merycopotamus cf. *dissimilis*.
Dicoryphochoerus titanoides
Dicoryphochoerus vagus
Hippohyus lydekkeri
Hippohyus grandis
Dorcatherium majus
(?) *Antilope* (?) *planicornis*
Selenoportax lydekkeri
Pachyportax latidens, type variety
Sivaonyx bathygnathus

The following Dhok Pathan genera occur also in the Tatrot stage, represented by species which may not be different from those in the Dhok Pathan: *Hippopotamus ; Sivachærus ; Proamphibos ; Hipparion ; Stegodon ; Stegolophodon* (if the locality Lehri from which *S. stegodontoides* was obtained is Tatrot); *Agriotherium* (if the species *A. palæindicum* is Dhok Pathan). Reduncinae which

occur in the Dhok Pathan stage may belong to the same genera as those from Tatrot. They agree in size and in degree of development.

Considering the poverty of the Tatrot fauna, it seems useless to assume that various Dhok Pathan genera have become extinct, because they have not been found at Tatrot, but it seems likely that most of the forms corresponding to those which became extinct in Europe before Roussillon did not persist into the Tatrot stage. We have, however, to take into account that many of these were Pontian invaders into Europe, which may not have been the case in India. Such are forms like the Giraffidae, the Chalicotheriidae, *Enhydriodon* and the Catarrine monkeys which we know to have existed in India up to the Pinjor or later.

Genera in the Tatrot which are the same as those of the Pinjor, though the species are generally different, are: *Mastodon* (*Pentalophodon*) possibly identical with the species *M.* (*Pentalophodon*) *falconeri*; *Stegodon*, as the species *S. bombifrons*; *Elephas* (*Archidiscodon*) cf. *planifrons*; *Equus* sp.; *Hipparion* sp.; *Sus*, as the species *S. peregrinus*; *Potamochoerus*, as the species *P. palaeindicus*; *Sivatherium*; *Sivatragus*, as the species *S. brevicornis*; *Sivadenota* (?) as the species *S.* (?) *sepulta*; *Hydaspicobus* as the species *H. auritus*; *Indoredunca* (?) as the species *I.* (?) *theobaldi*.

The only Tatrot genus, so far as we are aware, which does not persist into the Pinjor is the early Bubaline *Proamphibos*, which is ancestral to *Hemibos* and possibly to *Bubalus*. Of the various antelopine species from Tatrot which have been referred to Pinjor genera, all of them are represented by species which are undoubtedly more primitive than the Pinjor species. The same applies to *Potamochoerus palaeindicus* and *Sus peregrinus*.

The occurrence of *Equus* and *Elephas* (*Archidiscodon*) cf. *planifrons* as newcomers in the Tatrot, does not seem to me to militate against assigning it to the Astian stage, in spite of the fact that they do not occur in Europe previous to the Villafranchian, seeing that they are invaders into both regions, unless India happens to be the country where *Elephas* originated, in which case its earlier appearance in India is even less surprising.

In every other respect, so far as the meagre fauna of Tatrot enables us to judge, the differences between it and that of the Pinjor are quite comparable with and of the same quality as those between the faunas of Roussillon and the Villafranchian.

Failing material for a more detailed comparison between the faunas of Tatrot and Pinjor, it may serve as an additional argument for keeping the two stages distinct if it can be shown that while the Tatrot and the Dhok Pathan faunas possess certain affinities to one another as listed above, which that of the Pinjor does not share, the latter on the contrary indicates very clearly that it belongs to the same epoch as the Villafranchian of Europe and of Nihowan in China and is obviously older than the Cromerian or Sicilian.

The abundance of *Elephas* (*Archidiscodon*) *planifrons* in the Pinjor, as in the Villafranchian of Europe, affords one of the strongest proofs of their identical age. This species coexists in the Villafranchian with *Elephas* (*Archidiscodon*) *meridionalis*, but the latter species alone persists into the Cromerian. *Elephas* (*Loxodon*) *antiquus* appears in Europe for the first time in the Cromerian. Except that *E. meridionalis* has not been certainly recognized in the Pinjor, although Depéret has suggested that *E. hysudricus* is the equivalent of a later mutation of that species which occurs at Saint Prest, and that *E.* cf. *planifrons* appears in the Tatrot, the geological distribution in India agrees perfectly with a correlation of the Pinjor with the Villafranchian. *E. hysudricus* probably occurs high up in the Pinjor and persists into the Boulder Conglomerate stage, while *E.* (*Loxodon*) *namadicus* is absent from the Pinjor but is plentiful in the Narbada beds and in the Lower Karewas of Kashmir. The occurrence of *Mastodon arvernensis* in the Villafranchian is paralleled by that of *Mastodon sivalensis* in the Pinjor. The presence of *E. namadicus* at Nihowan points to a somewhat younger age than the Villafranchian for those deposits.

The relationship of *Rhinoceros platyrhinus* to *Diceros* (or *Dicerorhinus*) *etruscus* is not proved. If the Indian species is a *Coelodonta*, as Colbert inclines to think, then it is certainly much more primitive than *C. antiquitatis* of the later Pleistocene. Matthew (1929, p. 535) observed that he would have expected that stage of evolution in the Miocene rather than in the Pliocene.

Following Hopwood (1937, p. 907) there are both Zebrine and Caballine types of *Equus* in the Pinjor, represented by *E. sivalensis* and *E. namadicus* which are Caballine and *E. cautleyi* which is Zebrine. The latter species is intermediate in size between *E. robustus* and *E. greveyi*. The small horse *E. stenonis*, which is much more common in Italy than the large *E. robustus*, has not been recorded from the Pinjor. In the Cromerian the Caballine type appears

to be much more plentiful than the Zebrine type, though a later mutation of *E. robustus* occurs. Except for the bare record by Lewis of the occurrence of *Equus* at Tatrot, I know nothing of its nature.

Teilhard and Pivetean have provisionally referred a Chalicotheroid from Nihowan to the same genus, *Nestoritherium*, as the Pinjor *N. sivalense*, though the teeth are more hypsodont than those of the latter.

The Nihowan deposits have also yielded the large *Paracamelus gigas*, which according to Teilhard and Piveteau is a true *Camelus*, though in a slightly more primitive stage than the living forms and also than *C. sivalensis* and *C. antiquus* of the Pinjor.

The only Bovine known from the Villafranchian of Europe is *Leptobos*, represented by closely allied species to which the names *L. elatus*, *L. etruscus* and *L. stenometopon* have been given. They are as plentiful as *Leptobos falconeri* is in the Pinjor of India. The latter is for the most part more primitive than the European forms, except perhaps in the greater degree of deflection of the supraoccipital into the plane of the occipital. The genus is not known to have persisted in India beyond the Pinjor, but dentitions from the Cromerian of Süssenborn have been referred to it. In the Djetis stage of Java it certainly exists, but in a much more progressive stage.

From the Cromerian of Europe *Bison priscus* is recorded and possibly *Bos primigenius*, but these species are far more progressive than the Pinjor *Bison sivalensis* and *Bos acutifrons*. *Bison palaeosinensis* of Nihowan is perhaps more nearly the equivalent of the Indian species. On the other hand neither of these two extra-Indian areas contains the primitive Pinjor forms *Hemibos*, *Bucapra* and *Platybos*.

The Villafranchian antelopes of Europe are not as a rule comparable with those of the Pinjor. The Caprinae are represented in the former region by forms like *Deperetia ardea*, *Procamptoceras brivatense*, *Nemorhaedus meneghinii*, and *Megalovis latifrons*, and at Nihowan by a true sheep, *Ovis shantungensis*. The only Caprrinæ so far known from the Pinjor belong to the genus *Sivacapra*, which though it may be on the same lineage as *Capra* or *Hemitragus* is in a far more primitive stage, comparable only to that of *Tossunoria* of the Pontian of China.

The hyænas of the Pinjor are quite comparable with those of Europe. *Crocuta sivalensis* is closely allied to *C. brevirostris* of the Villafranchian. This is replaced in the Cromerian by *C. spelæa*.

Sivafelis brachygnathus is closely allied to both *Felis arvernensis* of Europe and to *Cynaelurus pleistocaenicus* of Nihowan. The type is absent from the Cromerian. *Megantereon falconeri* is a near relation of the wide spread *M. megantereon* of the Villafranchian of Europe, though slightly more progressive. The species does not persist into the Cromerian.

I have so far dealt with the views which are peculiar to De Terra, Teilhard and Lewis, which involve the Upper Siwaliks only, and which Colbert gives no indication of sharing. I now approach the main subject of this paper, the correlation of the Middle and Lower Siwalik stages, on which Colbert has laid the greatest stress. Lewis bases his correlation of this part of the series on the same premises as Matthew and Colbert and is more or less in agreement with those authors, though he considers each stage as somewhat more ancient than they do, thus approximating to my own view.

The correlation of the Dhok Pathan stage of India with the Pontian of Europe remains, as it has always been in my mind, the foundation of the whole correlation adopted. The other stages fall into place in the time scale, mainly because of the relation which their respective faunas bear to that of the Dhok Pathan, although strong confirmation is afforded both in the case of the Pinjor and the Chinji fauna by the indication which they afford of equivalent genera and species to those which occur at Perrier and La Grive Saint Alban respectively.

Matthew was less concerned to admit this close correspondence between the Dhok Pathan and the Pontian faunas than to demonstrate that the occurrence of *Hipparion* in India at an earlier date than the Dhok Pathan proved conclusively that the Dhok Pathan stage must be later than Pontian, from which he considered that its first appearance in both America and Europe dates: so much so that it seems as if he had often gone out of his way in an attempt to show that the Dhok Pathan species are more progressive than those of deposits like Pikermi, Samos, Maragha and the Red *Hipparion* beds of China.

Colbert (1935, pp. 21, 22) has taken a more liberal view. He grants that the character of the respective stages of the Siwaliks when compared with those of European faunas seems greatly in favour of Pilgrim's views of correlation. In effect he admits that he would adopt the same correlation himself, were it not for the occurrence of *Hipparion* in the Lower Chinji.

Attempts have been made to reconcile the inconsistency of the faunal facies of the Siwalik stages with the assumption that *Hipparion* reached India from North America by: (1) on the one hand, advancing evidence that the earliest *Hipparion* of North America dates from the Sarmatian, and (2) on the other, stressing the fact that *Hipparion* appears in Europe in beds of Sarmatian age. The evidence in favour of the first of these has been succinctly summarized by Lewis (1937, p. 195). It should be remarked that McGrew and Meade (1938, p. 106) dispute Lewis' assumption that the Puente and Mint Canyon beds of California are Miocene. They, therefore, regard *Hipparion* as dating from the Lower Pliocene in America, from which they infer not only that the Chinji is but little older than the Pontain, but also that the Sarmatian of Europe should be placed into the Pliocene. Regarding the second the Upper Sarmatian age of the Sebastopol fauna has been commonly accepted and other occurrences of *Hipparion* in Eastern Europe go to confirm this. The most recent example of such Sarmatian occurrences of *Hipparion* in Europe has been admirably recorded by Tobien (1938, p. 177). He has also discussed other supposed Sarmatian finds of the same nature. No other identifiable mammalian remains were associated with *Hipparion*, except in the case of Sebastopol. There is, however, no reason to believe that any of these deposits are much older than the latter and in any case are sharply distinguished from the Tortonian of La Grive Saint-Alban. Nor is the contrary to be expected, since nothing seems to be so clearly established as the fact that this is a fauna which invaded Europe suddenly, and that these invaders, whether they arrived in the Sarmatian or the Pontian, more or less ousted and usurped the place of the previously existing fauna. In other words it is a fauna of Pontian not of Tortonian facies which entered Europe at the stage of Sebastopol. The question to be asked is: does the general composition of the Chinji fauna harmonize with such a facies? In Colbert's and my opinion it does not. Lewis does not enter into this side of the subject, but presumably he is disposed to accept Matthew's and Colbert's explanation of the facts. On the contrary I consider that the Chinji fauna might reasonably have occupied during the Tortonian, if not the same, at any rate an outlying part of the Central Asiatic region, which a stage later was to people Europe with Sarmato-Pontian migrants. I shall, therefore, endeavour to show that any other correlation which

differs materially from the one I have adopted is incredible, if not actually impossible.

It has been shown by Pilgrim, Bohlin and Colbert that the Chinji fauna contains many species which are very closely allied to Tortonian forms of *Conohyus*, *Listriodon*, *Macrotherium*, *Dryopithecus*, *Amphicyon*, or which are more primitive than allied species which make their first appearance in Europe in the Sarmatian or Pontian, such as primitive Tragelaphinæ (*Sivoreas* compared with *Prostrepsiceros*); primitive Boselaphinæ, (*Strepsiportax gradiens* and *S. chinjiensis* compared with *Strepsiportax* (?) *latifrons*); *Giraffokeryx* as compared with *Palaeotragus quadricornis* and the Helladotherines; *Lycaeyna proava* and *L. chinjiensis* as compared with *L. chaeretis*; *Crocuta carnifex* as compared with *C. eximia*.

According to Matthew's and Colbert's view, in spite of this ancient affinity and of its containing no species which is similar to or at the same stage as any Pontian species except *Hipparion* the Chinji stage is not Tortonian but Pontian. Similarly the Nagri fauna (see pages 47-50) which contains *Strepsiportax*, closely allied to *S.* (?) *latifrons* of the Sarmatian of Europe, and from which the typical Pontian Giraffoids, as well as *Tragocerus* and many other genera are absent, is not Sarmatian but Pontian or post-Pontian. The Dhok Pathan fauna which exhibits a very close parallel to that of the Pontian of Europe, with many almost identical species, is not Pontian but Middle Pliocene (Astian), the equivalent of Roussillon and Monpellier.

A detailed comparison of the Dhok Pathan fauna with that of the Pontian of Europe and China is unnecessary, since this was made by Pilgrim, first in 1913 (pp. 280-307) and later in 1931 (Pilgrim, 1931, p. 152), and their close correspondence may be seen from a study of the faunal lists of Colbert (1935, pp. 29-36) and Pilgrim (1938, pp. 5-7). For easy reference, however, the closest specific affinities found in the faunas under consideration may be tabulated here.

Mastodon (*Choerolophodon*) *corrugatus* to *Mastodon* (*Choerolophodon*) *pentelici* of Pikermi.

Mastodon (*Tetralophodon*) *perimensis* to *Mastodon* (*Tetralophodon*) *longirostris* of Eppelsheim, etc.

Listriodon pentapotamiae, a survival from the Chinji, to *L. splendens*, a survival from the Tortonian.

Tragocerus punjabicus to *T. amalthea*.

Gazella lydekkeri to *G. capricornis* and *G. paotehensis.*
Tragoportax islami to *T. leskewitschi* of Sebastopol.
Proamphibos (?) *lachrymans* to *Parabos* (?) *macedoniae.*
Giraffa punjabiensis to *G. attica.*
Hydaspitherium grande to *Helladotherium duvernoyi.*
Indarctos salmontanus to *Indarctos* cf. *atticus.*
Plesiogulo brachygnathus to *P. brachygnathus* of China.
Sivaonyx bathygnathus to *S. hessicus.*
Enhydriodon falconeri to *E.* (?) *latipes* of Pikermi.
Ictitherium sivalense to *I. wongi* of China.
Lycyaena macrostoma to *L. chaeretis.*
Crocuta mordax to *C. eximia* and *C. variabilis.*
Crocuta gigantea var. *latro* to *C. gigantea* of China.
Paramachaerodus pilgrimi to *P. orientalis.*
Machairodus or *Epimachairodus* sp. to *Machairodus* and *Epimachairodus* sp. of Europe and China.
Hystrix sivalensis to *Hystrix primigenius.*

Matthew and Colbert consider that the Tatrot fauna, which contains the early Bubaline, *Proamphibos*, closely allied to *Parabos* of Montpellier, but lacks not only more advanced Bubalines but also *Leptobos* and primitive Taurina is not Astian, as the Bovine fauna would indicate, but the equivalent of the Villafranchian deposits of the Val d'Arno, Perrier, Senèze and Nihowan (China).

Finally, pursuing the same sequence of correlation which they observe throughout, they regard the Pinjor stage with *Elephas* (*Archidiscodon*) *planifrons*, the early Bubaline *Hemibos*, primitive forms of *Bos* and *Bison*, species of *Crocuta* which are closely allied to Villafranchian species, and the primitive goat, *Sivacapra*, as contemporaneous not with the *Elephas planifrons* beds of the Villafranchian, but with the *Elephas antiquus* beds of the Sicilian or Cromerian.

We have to infer from Matthew's and Colbert's correlation that the demonstrated European correspondence of the Indian faunas is merely homotaxial, and must be due either to migration from Europe to India or from some region midway between Europe and India which furnished migrants to Europe a stage earlier in each case than it did to India.

Matthew and Colbert refer to the general process as I have outlined it as exemplifying a series of "relict faunas". The term "relict fauna" is inapplicable. A relict fauna is one which being

originally much more widely distributed than it became later, has become confined from some cause or other to a restricted portion of its original area of distribution. The classic example of such a relict fauna is that of Australia, which provides us at the present day with the much modified descendants of a fauna which in the Cretaceous or earlier was of world wide distribution. The living fauna of Madagascar, consisting mainly of Lemuroidea with peculiar types of Carnivora, Rodentia, and Insectivora is a relict of the Eocene. Africa at the present day contains a relict fauna in the persistence of forms like the Tragulidae, the loxodont type of Elephant, *Rhinoceros*, the Giraffidae, most of the antelopes, *Hippopotamus*, the Tubulidentata (*Orycteropus*), the anthropoid apes, and many others of which some existed in Europe as lately as the Pleistocene, such as *Elephas Hippopotamus* and *Rhinoceros*, while the Tragulidæ, *Orycteropus*, the anthropoid apes and the majority of the antelopes died out in Europe as in most other parts of the world as early as the Pontian. There are many instances scattered throughout the world of faunas which at various periods contained relict forms, in some cases few, in others many in number. Thus in India itself *Hyaenaelurus* in the Kamlial stage is a relict of the Upper Oligocene, which persisted in India after it had died out elsewhere. In the Chinji, Hyænodonts, Proælurinæ and the *Palaeochoerus* type of Suid are obviously relicts. Even to-day, Tragulids, gibbons, elephants, and others less obviously so are relicts. In fact modern India shares with Africa but in a much smaller degree the possession of a fauna which in the Pleistocene or earlier was distributed over Europe and Asia.

It will be realized that such relict faunas and relict types are in a wholly different category from that in which we must place the successive fossil faunas of India which according to Matthew and Colbert represent those of one stage earlier in Europe, Central Asia and elsewhere. The constituents of each of these faunas are not in any sense survivals from the fauna of the preceding stage, but products of a contemporaneous migration, the forms allied to which perished in Europe or Central Asia simultaneously with the arrival of their congeners in India. Moreover, the migrants themselves did not flourish in India, as did the relict faunas of Australia, Madagascar and the African continent, but died out within the period of their migration.

Even if we suppose, which is indeed more likely, that the centre of distribution lay, not in Europe or Central Asia, but in a region

still unknown, situated between India and Europe, we are still faced with the curious circumstance that the fauna, while reaching Europe and Central Asia earlier than it reached India, died out immediately in its adopted country, even assuming that it may have continued in the country of its origin.

Geological history provides us with instances of the retarded migration of certain forms or even of an entire fauna from the country of its origin. This may be explained by the removal of physical barriers which had previously existed or by a change of climate or by both causes. The best instance of this in the case of terrestrial faunas which can be adduced is that of the Upper Sarmatian and Pontian mammals of Europe, which are so markedly different from those of the preceding stages embraced in the Miocene that it is only explainable on the assumption of a more or less sudden migration which had not been possible hitherto. When once the migration routes had been opened, however, contemporaneous migration occurred and fresh invaders entered Europe, in most cases almost simultaneously with their appearance in adjacent regions without the retardation which had occurred during the Miocene.

I can, however, find no parallel, at any rate in the case of land faunas, to what Matthew and Colbert suppose to have taken place in India. We might perhaps imagine that the Pontian fauna was hindered from some cause or other from entering India contemporaneously in the Chinji period, but after the removal of the barriers one would expect that fauna which entered India in the Dhok Pathan period [*i.e.*, in the Middle Pliocene (Astian), *ex hypothesi* Matthew and Colbert] to have been accompanied at any rate by some members of the contemporaneous Astian fauna of Europe. Let us see how far this expectation is realized.

Generic identities exist. *Hippopotamus*, in both regions an invading form, is extremely rare in the Dhok Pathan. Though it has not been found at Rossillon or Montpellier, yet it occurs in the Casino lignites which are believed to be only slightly younger than Pikermi and in the beds of the Wadi Natrun in northern Africa which are considered to be of Astian age. Its value as evidence of a similar age for the beds of Dhok Pathan and the Astian is somewhat discounted by our ignorance of its origin or adaptive centre of radiation. If it is related to the Anthracotheres, then it might be imagined that the centre in question lay so near to India, where Anthracotheres are more abundant than elsewhere, that it would

not be surprising that it should have reached that country earlier than Europe. The early arrival of the Suidæ into India may be explained in a similar way. Touching the possibility of an identity between the Astian *Potamochœrus provincialis* and the Dhok Pathan species which have been named *Propotamochœrus*, the more primitive character of the latter is shown by the less scrofic structure of the male lower canine and the simpler construction of the main cusp of P_4. The Dhok Pathan *Gazella lydekkeri* is undoubtedly more primitive than the Astian *Gazella borbonica*. The primitive buffaloes, *Parabos cordieri* and *P. boodon* of Montpellier are certainly allied to forms from the Dhok Pathan, which have been attributed to the same genus as *Proamphibos lachrymans* of the Tatrot. The two genera are not however identical, the European form being more primitive as regards the teeth. Moreover a presumably ancestral form exists in the Pontian of Europe as *Parabos* (?) *macedoniae*, while the Dhok Pathan stage has yielded another species referred to *Proamphibos*, *P.* (?) *hasticornis*, which has certainly more primitive skull characters than *Parabos*. Amongst the Carnivora the species *Megantereon* (?) *prœcox* from the Nagri (or Dhok Pathan) stage of India, supposing it to be generically the same as *Megantereon megantereon* of Roussillon, is at any at smaller and more primitive than the latter. *Agriotherium palaeindicum* which presumably occurs in the Dhok Pathan stage side by side with two species of *Indarctos* is undoubtedly more primitive than *Agriotherium insigne* of Montpellier. *Vishnuictis salmontanus* is not closely related to *Viverra pepratxi* of Roussillon. *Hipparion crassum* of Roussillon is a more advanced form than either of the Dhok Pathan species of *Hipparion* in the atrophy of the protostylid in the lower premolars and of the median accessory cusp in the lower milk molars, in the broader median metapodials and the less prominent lateral metapodials.

On the other hand the Ursinæ represented by *Ursus* (*Helarctos*) *arvernensis*, the Canidæ represented by *Vulpes donnezani*, hyænas of the type of *H. striata* represented by *H. arvernensis* at Roussillon, and rodents of a modern type such as *Mus donnezani* do not appear in India until the Pinjor stage or later, although their absence from the Tatrot fauna may be only apparent and due to the poverty of the latter.

On the whole contemporaneous migration of the Astian types of Europe into the Dhok Pathan deposits of India, if it took place

at all, was much less abundant than one would expect, judging by the extremely close correspondence of many species from Pikermi, Samos and the *Hipparion* beds of China with those of the Dhok Pathan.

To consider the earlier horizon of Chinji, regarded by Matthew and Colbert as Pontian. Although its fauna is essentially of a Vindobonian type, yet according to Colbert it must have largely migrated to India in the Pontian accompanied by the contemporary form *Hipparion*. My comment on this theory is the same as above. It would be reasonable to expect that other contemporary forms should have entered India either from Central Asia or Europe in addition to *Hipparion*. At first sight the Chinji fauna, containing as it does large quantities of antelopes, as well as Giraffidæ, Suidæ, Hyænidæ of the type of *Crocuta eximia* and *Ictitherium* seems to offer a prospect of fulfilling this expectation. *Gazella*, it is true, occurs in the Chinji, but the vast bulk of the Bovidæ consists of a group of antelopes which bear little affinity to those of Pikermi and Samos, but are related rather to *Boselaphus*. The sole representatives of this subfamily in Europe apart from *Tragocerus* are *Protragocerus chantrei*, "*Tragocerus*" *leskewitschi*, "*Tragocerus*" *latifrons* and *Miotragocerus monacensis*. The first of these is from the Tortonian beds of La Grive Saint Alban, the second from the Sarmatian of Sebastopol, and the two last from the Sarmatian of the Vienna basin. The first is only known by fragmentary remains but is related both to *Strepsiportax* and *Tragoportax*, the second is probably a *Tragoportax*, the third is probably a *Strepsiportax* but more advanced than either of the Chinji species; the last is allied to the Chinji *Sivaceros* but is much more advanced in the direction of *Tragocerus*. The large Hippotraginæ of Pikermi and Samos such as *Palaeoryx*, *Protoryx*, *Microtragus* and equally those of China which include in addition to these the genera *Sinotragus* and *Prosinotragus* are absent from the Chinjis. The numerous Pontian Tragelaphinæ of Europe are represented by but a single genus, *Sivoreas*, which is smaller and more primitive than any Pontian form. The ubiquitous genus *Tragocerus* does not reach India until the Dhok Pathan, although its probable ancestor *Sivaceros* appears in the Chinji.

Matthew and Colbert (Colbert, 1935, pp. 25, 26) consider that the Giraffidæ afford a strong proof of the Pontian age of the Chinjis. In my opinion, however, too little is known of the origin

and phylogeny of the family to base any far reaching conclusions on them. Excluding the little known forms *Propalæomeryx* (= *Progiraffa*) and *Giraffa* (?) *priscilla*, *Giraffokeryx* is the only Giraffoid definitely known from the Chinji stage. *Giraffokeryx* may be quite properly regarded as a Palaeotragine allied to the Pontian species *P. quadricornis*. Its horns and other characters however, clearly indicate that it belongs to a different genus from *Palæotragus*. I am still almost convinced that it represents an early specialization ancestral to the Sivatherines and from Bohlin's and Colbert's remarks it may be inferred that they are inclined to hold the same opinion. In any case it is agreed that the Palæotraginæ are the most primitive of the various sub-families of the Giraffidæ. On the assumption that the Chinji is Pontian, the typical large Sivatherines which occur at Pikermi as *Helladotherium* might we imagine have accompanied *Hipparion* to India, as also the more characteristic large Palæotragines such as *Samotherium* of Samos and China, and *Alcicephalus* of Maragha and Central Asia, as also the Giraffinæ, *Orasius* or *Giraffa*. I cannot, therefore, see how the Chinji Giraffoids add any evidence for correlating the Chinji with Pikermi or the Hipparion fauna of China.

The Chinji Suidae include species of *Listriodon*, *Conohyus* and *Palaeochoerus* which are almost too close to Vindobonian species of Europe to be called relicts instead of migrants. Their almost identical features to the European species is truly remarkable. It would be still more surprising if they persisted into the Pontian of India according to Colbert's theory. It may be remarked that *Listriodon* persists into the Pontian of Europe, but it equally is found in the Dhok Pathan. There also exist in the Chinji what may be endemic groups of Suidæ, to which the names of *Propotamochoerus* and *Dicoryphochoerus* have been given. They resemble nothing which has been found in the Pontian of Europe. On the other hand the type of *Microstonyx* which extends from Europe to China did not penetrate to India.

It is true that Hyænidae allied to *Crocuta eximia* and *Lycyaena chaeretis* occur in the Chinji stage, but *Crocuta carnifex* is clearly more primitive than *C. eximia* and *C. variabilis*. Hyænidae at the same stage of evolution as the two last named species, wide spread as it was in Europe and Central Asia, did not reach India before the Dhok Pathan. *Lycyaena parva* and *L. chinjiensis* are very much smaller species than the large *L. chaeretis* and may be ances-

tral to it. The larger type of Pikermi is unknown in India before the Dhok Pathan, where *L. macrostoma* is closely allied to it.

It is the same story with every group of mammals whose remains in India are well enough known to enable a judgment to be formed. The Pontian *Sivaonyx* and *Enhydriodon* did not migrate to India in the Chinji stage, although a form which may be ancestral to both of them, *Vishnuonyx*, existed at Chinji. The large Machærodonts and Hemicyoninæ which are a feature of the Pontian of Europe and China fail to appear in the Chinji any more than the primitive buffalo, *Parabos* (?) *macedoniae*, or *Orycteropus*, though the latter has been found in the Nagri stage.

I may again revert to the argument which has already been brought forward elsewhere (Pilgrim, 1931, p. 151) and has been in part alluded to in the preceding pages. Matthew and Colbert suppose that the Chinji is of Pontian age and that its fauna largely arrived in India at a time when a very different fauna inhabited Europe itself. In spite of this it seems very remarkable, to say the least, that so many forms should exist in the Chinji which are more primitive than, if not actually ancestral to forms in the Pontian of Europe and the Dhok Pathan stage of India alike. Many of these lineages are actually unknown in Europe before the Pontian, so that even if they migrated from India to Europe, they could not have done so in the Dhok Pathan, since according to Colbert's hypothesis the Dhok Pathan is post-Pontian. To name a few of such forms. *Sivaceros* is an ancestral type of *Tragocerus*; *Sivoreas* of *Prostrepsiceros*; *Strepsiportax* of "*Tragocerus*" *latifrons*; *Vishnuonyx* of *Sivaonyx* and perhaps of *Enhydriodon*; *Crocuta carnifex* of *Crocuta eximia*, *C. variabilis*, *C. gigantea* and *C. mordax*; *Propontosmilus sivalensis* of *Epimachairodus*; *Lycyæna proava* and *L. chinjiensis* of *L. macrostoma* and *L. chaeretis*. Finally the Chinji stage contains species of Proboscidea which are ancestral 1. to *Mastodon* (*Choerolophodon*) *pentelici* and *M.* (*Choerolophodon*) *corrugatus* and 2. to *Mastodon longirostris* and *M. perimensis* (see Hopwood, Appendix pp. 72-75).

This brief review of the Chinji fauna entitles us to ask for a reasonable explanation of the fact that *Hipparion* alone of the rich Pontian fauna was able to reach India contemporaneously with its appearance in Central Asia and Europe.

It might be contended that the Chinji fauna, though pre-Pontian, is not contemporaneous with the Tortonian fauna of La Grive Saint

Alban, but as Lewis thinks, with that of the Upper Sarmatian of Sebastopol or even with that of the Sarmatian of the Vienna basin, which contains a few Tortonian species such as *Conohyus simorrensis*, *Anchitherium aurelianense*, *Amphicyon major*, *Ursavus*, *Aceratherium tetradactylum* and *Ceratorhinus sansaniensis*, and which probably belongs to the lower part of the Sarmatian. It is true that such a correlation either with the Upper or Lower Sarmatian would harmonize with the peculiar character of the Chinji fauna as ancestral both to the Dhok Pathan and the Pontian of Europe and China. On the other hand, the intermediate position of the Nagri fauna between those of Chinji and Dhok Pathan affords the best argument against this view.

The sharp lithological change from the bright red clays of the Chinji into pale green sandstones of the Nagri does not necessarily indicate any great interval of time between the two stages, so that certain species which have been found near the base of the Nagri may not be much later than those of the Chinji. At the same time since the fauna of Nagri itself, of Haritalyangar, of Bahitta and certain other localities in the neighbourhood of Hasnot lies some 1500 to 2000 feet above the base, these afford good evidence for the intermediate character which I have mentioned above.

The following may serve as instances of this. *Gaindatherium browni* from the Nagri stage, one mile south of Nathot, is also found in the Chinji, but is absent from the Dhok Pathan. *Macrotherium* passes up from the Chinji into the Nagri, but is absent from the Dhok Pathan. The typical Chinji Anthracotheroid, *Hemimeryx pusillus* is also present at Nagri, but is replaced in the Dhok Pathan by *Merycopotamus*. *Conohyus indicus* is a true survival of the Chinji *C. chinjiensis* but of much larger size. The genus does not persist into the Dhok Pathan but is replaced by *Tetraconodon*. Equally *Propotamochoerus* and *Dicoryphochoerus* are represented by identical or closely allied species in the Chinji and Nagri. The gigantic Dhok Pathan species *Dicoryphochoerus titan* has not, however, yet appeared in the Nagri. On the other hand the occurrence of a true *Sus* and of *Hippohyus* in the Nagri distinguishes it from the Chinji. *Dorcabune nagrii* is probably closer to the Dhok Pathan *D. latidens* than to the Chinji *D. anthracotheroides*. The Giraffidæ afford good distinctions between the three stages. *Giraffokeryx punjabiensis*, common in the Chinji, passes up into the Nagri,

but does not persist into the Dhok Pathan. A Giraffid intermediate in size between *Hydaspitherium megacephalum* and *Giraffokeryx punjabiensis* has been provisionally referred by Matthew (1929, p. 545) to *Vishnutherium* sp. indet. The large Sivatherines like *Hydaspitherium* and *Bramatherium*, which are typical of the Dhok Pathan do not, however, occur in the Nagri. It is likely that certain typical Chinji Boselaphinæ such as *Strepsiportax* and *Helicoportax* just enter the Nagri, but soon die out. The basal beds of the Nagri yielded the type skull of *Selenoportax vexillarius*. This species appears to be absent from the Chinji but is plentiful in the Dhok Pathan. *Pachyportax nagrii*, supposed to be ancestral to the Dhok Pathan *P. latidens*, is absent both from the Chinji as well as the Dhok Pathan. The genus *Sivaceros* is represented both in the Chinji as well as in the Dhok Pathan, but certain large species of it appear to be confined to the Nagri. *Tragoreas* (?) *potwaricus* represents a more primitive stage of development than either *T. oryxoides* of the Pontian of Europe or *T.* (?) *lagrelii* of the Pontian of China. So far it has only been found near the village of Nagri. The absence from the Nagri of the common Dhok Pathan genera *Tragocerus* and *Tragoportax* which are typically Pontian seems to be very significant.

Amongst the Carnivora *Amphicyon*, a typical Chinji genus, is also found in the Nagri but does not persist into the Dhok Pathan. *Sivanasua* does not persist into the Dhok Pathan, but is represented in the Nagri by a species *S. himalayensis*, which differs from the Chinji *S. palaeindicus*. *Vinayakia* occurs both in the Chinji and the Nagri but the Nagri species, *V. nocturna* is decidedly more advanced than the Chinji *V. sarcophaga*. The genus does not persist into the Dhok Pathan but seems to be replaced by *Mellivorodon*. *Crocuta carnifex*, the earliest representative of the Hyænid lineage which has a reduced protocone in p^4 is confined to the Chinji but a more advanced species *C. gigantea* var. *latro* is found both in the Nagri and the Dhok Pathan. *C. mordax*, close to the Pontian *C. eximia* and *C. variabilis* has only been found in the Dhok Pathan. *Megantereon* has not been found in the Chinji but the species *M. praecox* from the Nagri (or Dhok Pathan) stage of Haritalyangar is probably ancestral to forms which occur at later horizons. Considering the comparative poverty of the Carnivorous fauna of the Nagri stage no stress can be laid on the absence from it of numerous typical Dhok Pathan genera.

Since the Nagri fauna seems to fulfil precisely the requirements which would render it the equivalent of the Sarmatian of Europe, it does not seem probable that the older fauna of Chinji can be referred to the same age as any of the known Sarmatian faunas of that continent.

An unpublished remark of Dr. Hopwood has suggested to me one other possibility. This is that the Chinji fauna, though later in age than that of La Grive Saint Alban is earlier than any of the known Sarmatian faunas. It is quite conceivable that the mammalian faunas of the Upper Miocene of Europe do not represent a continuous chronological sequence and that none of the European deposits have so far yielded a fauna which is strictly contemporaneous with that of Chinji. Such a fauna might tend to bridge the remarkably abrupt gap between those of La Grive Saint Alban and the Sarmatian. Whether it should be termed Upper Tortonian or Lower Sarmatian is a matter of taste. The hypothesis is at present insusceptible of proof and in any case even if substantiated would hardly account for the pre-Sarmatian migration of *Hipparion* from North America into Asia. It serves, however, to emphasize the fact that I do not regard the correlation of the Chinji stage as so precise as that of the Dhok Pathan. In calling it Tortonian I have accepted it as the approximate equivalent of that of La Grive Saint Alban, merely because no other known fauna of Europe seems to fill the place.

From the comparisons made above (pages 446-464) between the Tatrot and Pinjor faunas and those of the Astian, Villafranchian and Cromerian of Europe, it is evident that no greater influx of the contemporaneous European and Chinese faunas of the Villafranchian and the Cromerian into India can be noticed than has been seen to be the case in Pontian and Astian times, using Matthew's and Colbert's chronology. In other words on their hypothesis migration into India has been *successively* retarded stage by stage throughout the long period extending from the Vindobonian to the Cromerian. Such a phenomenon is within all experience unparalleled and is to my mind incredible. The incredibility of the nature and chronology of the processes involved by our acceptance of Matthew's and Colbert's theory would be at once placed into the region of impossibility if we could show that India was the adaptive centre of any of the groups which have been assumed to migrate in this bizarre fashion. Although it would be rash to assert

that the Indian region formed the whole or even a part of such an adaptive centre, yet there is undoubted evidence that in the case of at least two important and mobile groups India must have been extremely near the adaptive centre, if indeed it did not form a part of it. These are (1) the Elephantoid and certain Mastodontoid branches of the Proboscidea; (2) the Bovinæ or oxen and buffaloes. The first of these groups is discussed on comparative lines in an appendix by my friend Dr. A. T. Hopwood. The second forms the subject of the succeeding pages.

THE BOVINAE.

The proof that the Bovinae were descended directly from some member of the subfamily Boselaphinae is, in my opinion, complete. It is elaborated in a recent work by myself on the Fossil Bovidæ of India (1939, pp. 140-157). Excluding the Tragocerina which belong to a specialized branch of the Boselaphinæ, somewhat off the line leading to the Bovinæ, there is no other part of the world in which, so far as we are aware, that subfamily is of more than sporadic occurrence. Throughout the Chinji, Nagri and Dhok Pathan stages Boselaphinæ are not only plentiful, but include several lineages, some of which such as *Pachyportax* and *Perimia* resemble very closely the primitive oxen. Other lineages beginning in the Chinji are that of *Sivaceros* which is the most probable ancestor of *Tragocerus*; the Helicoportacina, continued as *Selenoportax* in the Dhok Pathan; and a form *Sivaportax*, probably Dhok Pathan, which is more closely allied to *Boselaphus*. The last named genus and the related *Tetracerus* are Pleistocene and living forms, which so far as we know at present are confined to India, though the allied *Duboisia* occurs in the Pleistocene of Java. In Europe "*Tragocerus*" *latifrons* of the Sarmatian, mentioned above (page 461) cannot be separated generically from *Strepsiportax*. *Protragocerus chantrei* is a little known form from the Tortonian of Europe apparently with affinities to *Tragoportax* and *Strepsiportax*. "*Tragocerus*" *leskewitschi* from the Sarmatian beds of Sebastopol is probably assignable to the Indian genus *Tragoportax*. *Miotragocerus monacensis* from the Sarmatian of the Vienna basin is most nearly allied to *Sivaceros*, but in certain respects approximates to *Tragocerus*. In the deposits of Sze Chuan in Southern China, probably of Villafranchian age or slightly younger, a genus *Proboselaphus*

occurs, of which the nearest affinity seems to be found in the Dhok Pathan form *Perimia falconeri.* The chances are greatly in favour of the Bovinæ having originated in the region in which the ancestral Boselaphinæ predominate so overwhelmingly both as to numbers and variety of genera over the rest of the world.

The earliest true Bovinæ known from India occur in the Dhok Pathan stage of the Salt Range and the Irrawaddy series of Burma as two or three species, ancestral to *Hemibos* and *Bubalus*, to which I have given the name *Proamphibos.* A fourth, *Proleptobos*, from beds in Burma which are probably the equivalent of the Dhok Pathan, is ancestral to *Leptobos* and possibly to the Taurina. A Bovine is known by some limb bones and teeth from the Pontian of Salonica, which Arambourg and Piveteau refer to the same genus as the remains from the Astian of Montpellier and perhaps from Casino and the Wadi Natrun, described under the names of *Parabos cordieri* and *P. boodon.* More plentiful material of *Proamphibos* has been collected from the Tatrot stage. *Parabos* is closely allied to *Proamphibos* and like it is a primitive buffalo. Its dentition is somewhat more primitive and seems to resemble somewhat that of *Pachyportax. Leptobos* is represented in the Pinjor stage of the Upper Siwaliks by the species *L. falconeri* and in Europe by various closely related Villafranchian forms known under the names of *L. etruscus*, *L. elatus* and *L. stenometopon*, which are generally more progressive than the Indian species, though they retain a few more primitive features. In the Djetis stage of Java, perhaps Cromerian, *Leptobos groeneveldtii* represents a decidedly more progressive stage than any of the other species of *Leptobos. Leptobos* is the only Bovine definitely known from the Villafranchian of Europe. It is replaced in the Cromerian by *Bos* and *Bison* of a rather modern type. On the other hand side by side with *Leptobos* in the Pinjor stage numerous other genera occur : *Hemibos*, a stage of development intermediate between *Proamphibos* and *Bubalus*, species of *Bos, Bison* and *Bubalus* which are distinctly more primitive than the earliest representatives of these genera in Europe, as well as other genera such as *Bucapra* and *Platybos*, which have not been found elsewhere. Many of these species occur in extraordinary abundance, so as to dominate the fauna, at any rate after the Proboscidea. For the most part they seem to have disappeared from India when the older alluvium of the Narbada was deposited, *Bos namadicus* and *Bubalus palaeindicus* alone remaining so far as is known. Of these

two species one is closely allied to, if not specifically the same as the living Indian buffalo, and the other is with difficulty distinguished from the Pleistocene *Bos primigenius* of Europe.

At Nihowan in China, which is considered to be Villafranchian in age, a bison occurs, *B. paloeosinensis*, which seems to be as primitive as *B. sivalensis* of the Pinjor. In Sze Chuan, perhaps rather younger than Nihowan, *Bibos geron* has been found. This genus has not been recognized fossil in India. *Bos acutifrons* of the Pinjor is the most primitive species of true *Bos* which is at present known.

It is inconceivable that Europe should have been very near the area which furnished such a wealth of Bovine types to India. Failing a knowledge of the Middle and Upper Pliocene fauna of countries like Persia, Arabia or Asia Minor one cannot predicate that India was even a part of such an area, but that migration from it to India must have been easier and more plentiful than it was to Europe may, I think, be safely claimed. The occurrence of a progressive species of *Leptobos* and of progressive species of *Bubalus* and *Bibos* in the Djetis stage of Java tells equally in favour of the adaptive centre of the Bovinæ being remote from Europe.

In spite of these well founded conclusions we are forced to believe, if we accept Matthew's and Colbert's correlation, that the earliest known Bovine appeared in the Pontian of Europe; that it was not until the Astian that the subfamily reached India; nevertheless in these Indian deposits it was represented much more abundantly than in Europe, by at least three different forms, one of which, *Proleptobos*, is ancestral to *Leptobos*. Notwithstanding this, *Leptobos*, although plentiful in Europe in the Villafranchian, did not enter India until the Pinjor stage (*ex hypothesi* Cromerian or Sicilian). Similarly although the two European species *Parabos cordieri* and *P. boodon* are closely related to the Tatrot *Proamphibos lachrymans*, yet *ex hypothesi* the former belong to the Astian and the latter to the Villafranchian. In the supposedly Cromerian stage of the Pinjor it dies out and is replaced by numerous Bovine genera which dominate the fauna of that stage. Strange to say, all of these are absent from the Villafranchian of Europe except *Leptobos*. One cannot conceive of migrational conditions which furnished these forms, all of them primitive ones, to the Cromerian of India but provided Europe as well as Central Asia during the same epoch with but a diminished residue and those much more progressive ypes of *Bubalus*, *Bison* and *Bos* than those of the Cromerian

(*ex hypothesi*) of India. Were the centre of distribution of the Bovinæ in Europe itself the occurence of the various genera and species as hypothetically described above would pass belief, but if that centre adjoined India, as the facts seem to indicate, then it verges on the impossible.

In the preceding pages I have tried to show that Matthew's and Colbert's hypothesis* of successive migrations of mammalian faunas to India between the Vindobonian and the Pleistocene just one stage later than similar migrations to Europe is quite incredible in the face of the knowledge which we possess of the palæontology of these two parts of the world.

Two alternative solutions of the problem, either of which would reconcile the various known facts, have suggested themselves to me. The first of these is that the European correlation of the American Upper Miocene and Pliocene faunas might be predated by at any rate half a stage. I hesitate to stress this strongly in the face of the vast amount of the work that has been done on the American faunas, especially as my own knowledge of the subject is insufficient to warrant it without devoting more time and research to it than I am at present able to spare. I would, however, point out that the accepted correlation was originally based in great part on the first appearance in Europe and America respectively of two members of the Equidæ, *Hipparion* and *Equus*. If this were the only evidence in favour of it, it would be like arguing in a circle if we assert that because *Hipparion* appears in the Chinji stage of India, therefore the Chinji must be Pontian, seeing that it is an altogether unwarranted assumption on our part that *Hipparion* arrived in Europe and India simultaneously. Nor indeed is this at all likely to have been the case, when we consider that the Pontian fauna of Europe resulted from a sudden invasion from Asia. I am aware that other factors have been taken into consideration before the correlation was finally decided on, but speaking generally I think that it might be more profitable to try and correlate the Miocene and Pliocene faunas of America with those of India in the first place or better still with those of China, when future discoveries make them known to us. It is obvious that the correlation of the Chinese and Indian faunas with those of Europe is also more practicable. Taking the Pontian specifically, it seems to me that a closer correlation might be found between the Edson, Mount Eden, Hemphill, Rattlesnake and Thousand Creek faunas and

those of the European Pontian, the Hipparion fauna of China, and the Dhok Pathan of India than between the Republican River and Valentine faunas and the old-world ones named. For instance the presence in the American faunas mentioned above of species of *Simocyon*, *Indarctos*, *Agriotherium*, *Parataxidea* and *Plesiogulo* closely allied to those found in Europe, China and India seems to be very significant. Possible *Pseudælurus intrepidus sinclairi*, *Heterofelis catocopis* and *Martes glareae* which also exhibit rather close affinities to old world forms may also be of the same age. The absence of European Artiodactyla from America as early as this may be due to climatic hindrances to migration by the Behring Strait route.

No American writer has suggested this idea, and although I think that in time to come this explanation may prove to conform most nearly to the facts, I will now dismiss it, whether possible or not, from further consideration here and proceed to the second suggestion that I have to offer, that of a dual origin for *Hipparion*.

Matthew and Colbert consider that their migration hypothesis is more credible than that *Hipparion* should have originated independently in North America and Asia from two different species of *Merychippus*, with the corollary to suit the facts that the evolution of *Hipparion* in Asia actually predated its evolution in North America. Is this, however, really so?

During the last half century palæontologists have grown to believe that the development of any particular group of animals has for the most part taken place in one region of the earth and that from this centre the genera one by one, as they arose, have been distributed into other parts of the world. No doubt this is in a general sense true, but the recognition that other branches of the group have sometimes arisen elsewhere so as to originate another allied group, has been forced upon us. The ancestral form of such a group is presumed to be a migrant from the original radiative centre. It has been assumed either that the changed environment which such a migrant might encounter in its new home would inevitably lead to an altogether different type of development from that followed by the main stem, or that through some inherent tendency to variation the same forms could not be produced in two widely distant regions. Where the same genus has been found in different parts of the world the tendency has been to consider that it originated in one of these areas only, and reached the other

by migration. In other words scientific thought is distinctly opposed to a dual origin for genera.

To illustrate what I mean by an example. The probable ancestor of the *Agriotherium*, *Arctotherium* branch of the Homicyoninæ is *Ursavus*. The types of this existed in Europe in the Middle Miocene and certain species in America have been referred to the same genus. It is assumed that migration is responsible for this. The next member of the phylum which has been recognized is *Indarctos*. This genus is distributed in the Lower Pliocene almost continuously from Europe to North America. Again this distribution is thought to be due to migration. When, however, we meet a more advanced type, *Agriotherium* in Europe and India, and another equally advanced type *Arctotherium* in America, both probably derivable more or less directly from *Indarctos*, it is accepted without further question that *Agriotherium* arose from one species of *Indarctos* in Europe or Asia and *Arctotherium* from another species of *Indarctos* in America. If, on the contrary, it had been the case that *Agriotherium* and *Arctotherium* were generically inseparable, palæontologists would at once have demurred to a separate origin, but would have contended that the occurrence of *Arctotherium* in America was due to a third migration. Is it, however, logical to base this difference in thought on the mere chance that the variation of the evolving form has been in the one case little, in the other great ?

In early days one thought of evolution as proceeding in a regular sequence from one individual or at any rate one species to another. Now, students of evolution think of progress not as being in regular straight lines but as a series of anastomosing lines forming a network. The individuals of a group confined to one feeding ground vary and interbreed and the result in the course of years is the production of a new species. Where the members of a species become separate and keep to different feeding grounds another species of the genus may arise. The final outcome is that many species may exist in the same part of the world, but there is no reason to suppose that these have all sprung from a single original species. I see nothing strange in supposing that a particular community in any genus may wander so far from the original hordes, that it never returns to them but goes on developing apart. If the environment is very different from that which it has left, as must often be the case, then a new type arises, which is separable generically from that

evolved in the original centre of distribution, always supposing that the change is not so prejudicial to the migrant as to exterminate it. Where, on the other hand, the environment is not appreciably altered it seems quite natural that the differences between the species developing in the two areas should not possess generic value. More especially is this likely to be the case where the family is an ancient one and, as is common in ancient families, has little tendency to vary. Under such conditions I cannot refuse to believe that the trend of evolution may follow the existing tendencies which have been impressed upon it through the ages and that two different species which cannot be separated generically may arise in different parts of the world.

This concatenation of circumstances seems to be completely attained in the later members of the Equidæ. In North America their evolution has been very gradual and has followed in the main the same course in all the later branches of the family. Merriam (1919, p. 558) and Lewis (1937, p. 196) have stressed the fact that advanced species of *Merychippus* cannot always be distinguished from its descendant *Hipparion.* Moreover the open steppe conditions favourable to the habit of these animals are likely to have been approximately the same everywhere throughout the Holarctic region in the later Cœnozoic epoch. I will go so far as to say that for all we know to the contrary this type of evolution may have been the rule rather than the exception. In very few cases, however, could it possibly be susceptible of proof. In this connection it is of great interest to find that Hopwood (1937, p. 909), from the facts which he has observed concerning the geological history and distribution of the Zebrine and Caballine types of *Equus* inclines to the view that these two groups evolved independently from the animals grouped under *Pliohippus* and *Plesippus.*

In the case of two groups of species which had an independent origin, such as I have suggested for the American and Asiatic species of *Hipparion*, it might be supposed, in fact the contrary is almost inconceivable, that they should differ in certain ways from one another, and that these differences would be perpetuated in all the succeeding species of each group. It might also happen that evolution though following the course usual in the family was (1) in some parts of the anatomy faster and (2) in others slower than among the species which remained in the original centre of distribution. The curious circumstance might even result (3) that the new genus actually

developed earlier in the new area than in the old one. The first two of the possibilities suggested have certainly come about in the case of the Old World species of *Hipparion*, in the precocious complication of the enamel folds in the teeth on the one hand and in the retarded atrophy of the lateral metapodials on the other. It was this, no doubt, that induced Matthew many years ago to suggest that *Hipparion* of Europe was evolved separately from *Neohipparion* of the New World. The third possibility will be demonstrated to have taken place in the evolution of *Hipparion* from *Merychippus* if my views on the correlation of the Siwalik stages are accepted.

The failure so far to find *Merychippus* in Central Asia is no argument against a dual origin for *Hipparion*, since Tortonian deposits are still unknown in that region. Even its absence as well as that of *Hipparion* from the Tung Gur beds of supposed Sarmatian age is understandable, because that seems to be a forest rather than a plains fauna.

APPENDIX ON THE CORRELATION OF CERTAIN TERTIARY DEPOSITS OF INDIA AND EUROPE.

BY A. TINDELL HOPWOOD, D.SC., F.L.S, *Department of Geology, British Museum (Natural History).*

Dr. Pilgrim has asked me to put together a few notes on the correlation of the Middle and Upper Tertiary deposits of India and Europe, basing my arguments on the Proboscidea. Two of the Indian stages, the Dhok Pathan and the Pinjor, are directly comparable with European deposits on the evidence of the fossil Proboscidea they contain, and a third the Fatehjang, also yields results which are valuable as an indication, even though the comparisons are less precise. I have not discussed the work of other authors because it seemed preferable to attempt an independent solution, and also because adequately so to do would take up more space than is at my disposal in, an appendix.

I. General considerations on migration.

The period of the first appearance of immigrant forms is of primary importance in correlation studies (*cf.* Depéret, 1905, 1906). Under favourable conditions, the time needed for migration is of no geological consequence, even though animals such as the Bovinae,

which inhabit wooded or forested areas, will tend to travel less rapidly than others such as the Equidae, which dwell on grassy plains. It must, however, be difficult to apply the principle of immigrant forms when dealing with areas at or near the centre of evolution of a given group. For example, the genera *Bos*, *Elephas*, and *Equus* are all immigrants in the European area and one may properly employ the time of their first appearance as marking the beginning of a new phase of geological time (*cf.* Hopwood, 1935). But in India these same genera illustrate very vividly the disadvantages attaching to any attempt to employ them in this manner. The first two evolved in or near to northern India and probably appear in the Indian deposits at an earlier date than elsewhere, *i.e.*, *Bos* and *Elephas* probably mark the end of the Pliocene rather than the beginning of the Indian Pleistocene. *Equus*, however, is an immigrant in the same area, and the strata in which unequivocal remains of that genus are known to appear for the first time may be regarded as the base of the Pleistocene in India, but support should be looked for among other groups.

In the final analysis, animal migration seems to have its origin in the search for food. This one factor influences migration in two chief ways. First, the local climatic conditions may change, and the animals follow their retreating food supply. On the eastern part of the Serengeti plains there are many thousands of antelopes during the rainy season when food is abundant. When the rains cease, the ground dries, the supply of grass diminishes, and antelopes become progressively scarcer as the main herds follow their food in its retreat to the West. Such migrations are usually seasonal, but if the change in conditions is due to geological phenomena they are likely to be permanent. In any event, they are not as a rule of the same importance as those next to be discussed.

The second class of migrations comprises those due to direct competition for food. It is axiomatic that a given amount of food will suffice for a given population, and that if the population exceeds that limit, either the whole population goes short, or else the surplus must seek supplies elsewhere. The second solution obtains under natural conditions. The ultimate results of such migrations may manifest themselves in more ways than one, and they affect correlation so closely that further discussion may be helpful.

In a well-balanced community migration is unlikely to take place so long as the natural checks and balances remain undisturbed,

and evolution will continue *in situ* as it were. If however, one of the component groups evolves so rapidly as to exceed its former food requirements, then so far as that group is concerned the area will become overpopulated, and some members of the group must move farther afield or perish. Under such circumstances, fossil remains of the group will be restricted to the original area up to the time when migration took place, and they will there be found in deposits of earlier date than in those areas to which they migrated. An example of this phenomenon is afforded by the mastodontoid genus *Choerolophodon* Schlesinger [*Synconolophus* Osborn.] This genus evolved quietly throughout the Kamlial and Chinji stages, and typical teeth, though rare, are found in the latter. In Dhok Pathan times, it suddenly became a dominant form. Teeth of *Choerolophodon* are the commonest proboscidean fossils found in that stage, and it is very significant that the genus appears suddenly in the Pontian deposits of Maragha, Samos, and Pikermi.

The ultimate fate of the migrants depends more on the physical conditions they encounter than on anything else. If the conditions are favourable, they will travel rapidly and multiply quickly according to their nature; but if the conditions are not favourable, if they find their way barred by climatic or physical obstacles, or if the land they seek to enter already supports animals capable of competing with them, then progress will be slow. Consequently the time-lag between the appearance of the genus at its centre of evolution and its arrival at the limit of its ultimate area of distribution will increase, and it may even come about that when migration is at an end the survivors are no longer recognisable as being of the same kind as those which originally set out on the journey. As examples of the first possibility may be mentioned the spread of the African elephant from an unknown centre over the greater part of that continent in post-Pluvial times, and the speed with which the horse recolonised North America after it had been introduced by Europeans. As an example of the second, slower, sequence of events, the Miocene invasion of Europe by Equidae of American origin, and their transformation on the way from the Oligocene *Miohippus* to the familiar *Anchitherium* of the Burdigalian and Vindobonian.

Sometimes there is every appearance of swift migration, a temporary check, and then a renewal of migration, with the result that beds of the same age may have a false appearance of being

of different ages. In the Sarmatian deposits of France, Germany, and the Vienna Basin, the Equidae are represented by *Anchitherium*, whereas near Sebastopol beds of the same age contain the much more advanced genus *Hipparion*. But for the fortunate circumstance that the latter are intercalated between marine strata of undoubted Sarmatian age, there would have been no hesitation in assigning the Sebastopol fauna to the Pontian. It is certain that the Sarmatian sea which lay between the Crimea and the Carpathians prevented *Hipparion* from proceeding farther to the West, but once the way was open migration was resumed and proceeded very rapidly in Pontian times.

Throughout the Miocene and Pliocene, India or an immediately adjoining area was a great centre of Proboscidean evolution and several groups, including *Choerolophodon*, the stegodonts, and true elephants, appear to have arisen there. These three and some others eventually became migrant, they are mentioned in this place because recognisable teeth of the first two are found in India at a much earlier date than in any other localities, and this stresses the need for caution when dealing with the first appearance of the true elephants. Similar caution is needed when the Bovinae are considered.

II. The correlation of the Fatehjang, Dhok Pathan and Pinjor.

In considering the correlation of the Siwalik stages with those of Europe, one would wish to extend ones comparisons to Burma, but this is not practicable because it is not yet possible to correlate the deposits of India and Burma by means of the Proboscidea. Indeed, so far as this particular group is concerned, the fossil Proboscidea of the pre-Pleistocene deposits of Burma appear to have closer affinities with those of Borneo and Java than with those of India, a fact which suggests that during part of the Tertiary, probably the Upper Miocene and the whole of the Pliocene, Burma supported a terrestrial fauna belonging to a different biological province from the Indian fauna.

In India, the Proboscidea were invaders during the Fatehjang stage, but in the later stages they were indigenous, and except in a few well-defined instances they ceased to be directly comparable with those of Europe. No matter which of the European genera is considered, all the Proboscidea found in that continent are immigrants. Never-the-less, three of the Indian stages, namely the

Fatehjang, the Dhok Pathan, and the Pinjor are marked by the immigration or emigration of Proboscidea; if their European equivalents can be established the choice of possible equivalents of the remaining stages will drastically be curtailed.

Fatehjang Stage.—The earliest known Proboscidea found in India are those of the Gaj series of Baluchistan. Pilgrim (1912) pointed out that in its morphology *Hemimastodon* is intermediate between *Palaeomastodon* and the trilophodonts of Sansan and Simorre. Forster-Cooper (1922) showed that the same genus, to which he referred as *Bunolophodon*, differs from the animals of Sansan and Simorre in that it has the last two premolars and the first two molars all in wear at the same time. These observations indicate that the Fatehjang stage is earlier than the Lower Vindobonian of Europe.

Direct comparison between the earliest mastodonts of Europe, namely those from the Orleans sands, and the specimens from Baluchistan is not easy, because the former have not adequately been described. Mayet (1908) mentioned a very important specimen from Beaugency and now in the Natural History Museum at Orleans. He did not publish a figure of the specimen, but he says that it enabled him to establish the dental formula in the upper and lower jaws as I1 : P2 : M3. This statement suggests that in this specimen the last two premolars and first two molars are in wear, and, one would presume, the fully formed third molar is still in the crypt. The isolated third molars found in the Orleans sand are slightly more advanced than those of *Hemimastodon*, but the difference is not so great, and these teeth together with the skull mentioned by Mayet indicate that, on the evidence of the Proboscidea alone, the Fatehjang stage should be compared with the Calcaire de Beauce, and that in any event it may safely be regarded as the equivalent of the Lower Burdigalian.

Dhok Pathan Stage.—The Dhok Pathan stage is distinguished by a profusion of specimens of *Choerolophodon*. This genus is indigenous to India; its remains are rare in strata older than the Dhok Pathan, although characteristic teeth are found in the Chinji stage (*e.g.*, tooth regd. Geol. Surv. Ind. No. A502), but when that stage is reached they are found so frequently, and in such variety, as to indicate that the genus had then achieved a dominant position. This same genus is found in Asia Minor and in Europe, but it is restricted to the Pontian deposits of Maragha, Samos, and Pikermi. These extra-Indian animals were described by Gaudry

as *Mastodon pentelici*: they are curious for the circumstance that whereas skulls of immature animals are fairly common, remains of adults, even isolated teeth, appear to be rare in collections.

The sudden appearance of *Choerolophodon* in the European deposits proves it to have been an immigrant. The only problem is to which of the Indian species does *Choer. pentelici* correspond? Of this there can be no reasonable doubt: although they are not identical, the specimens from Maragha and Samos are at exactly the same evolutionary stage as the species described by Pilgrim as *Mastodon corrugatus* and by Osborn as *Synconolophus dhokpathanensis*. If the Pontian were older than the Dhok Pathan one would expect the European species to be more primitive, for it is not credible that a migrant should be in advance of its contemporaries at or near the centre of evolution. The history of *Choerolophodon*, then, supports the view that the Dhok Pathan is the equivalent of the European Pontian.

There is an additional parallel between India and Europe when the European *Tetralophodon longirostris* (Kaup) is considered. This species is very closely allied to an Indian species which may, for the moment, be called *Tetr. perimensis* F. & C. The proper name of the latter is at present uncertain, but it has always been quoted under the name *M. perimensis*. It is well known that *Tetr. longirostris* is restricted to the Pontian deposits in Europe (*cf.* Schlesinger, 1922) but it is not always realised that this s ecies is a migrant, and that the supposed descent from *Tri. angustidens* is illusory. There are certain features of *Tetr. longirostris* which never occur in the supposedly transitional teeth. In India the position is quite otherwise. There are three-ridged teeth known from the Chinji stage which apart from the number of ridges and the height of the crown possess the essential features of *Tetr. perimensis*, and one has every reason to look upon them as the immediate ancestors of that species. Even in the Kamlial stage broken teeth have been found which seem to represent a still earlier form.

Tetr. perimensis itself is never common in the Salt Range and the Siwalik Hills, but it has frequently been found in the deposits of the Dhok Pathan stage on Perim Island in the Gulf of Cambay; indeed the majority of the specimens from Perim Island belong to this species. Once again we have to deal with a zoological type, in this case a species, which appears to have evolved quietly in India and which first becomes abundant in the Dhok Pathan stage.

In the Pontian of Europe there suddenly appears a so-called species which, at least in some individuals, is hardly to be separated from the Indian species of the Dhok Pathan stage.

Although the matter is complicated by the fact that as at present understood, both the Indian and the European "species" appear to be collective, it is significant that there is in each country a group of specimens which is doubtfully separable, and then only with difficulty, from the corresponding group of teeth in the other country. Moreover, the evidence that these teeth are indigenous to India, that they flourished during Dhok Pathan times, and that they suddenly appear during the European Pontian, is such a precise parallel to the history of *Choerolophodon* that they afford the strongest possible support for the view that on the basis of the fossil Proboscidea the European Pontian and the Indian Dhok Pathan stage are exact equivalents.

Pinjor Stage.—The fauna of the Pinjor stage has always attracted attention because it so closely resembles that of the Villafranchian of the Val d'Arno. The mastodonts found in the two deposits, *M. arvernensis* Croizet and Jobert and *M. sivalensis* Cautley, are so closely alike in the characters of their skulls and teeth that there is no justification for keeping them apart as separate genera. Indeed, it is not impossible that in course of time evidence will accumulate to show that they are geographical races of one species.

In the Chinji stage there was a group of mastodonts which had alternating cusps of the same structure as those of *M. sivalensis* and *M. arvernensis* but which were otherwise in a more primitive evolutionary condition appropriate to the lower geological horizon. These teeth appear in each of the higher horizons, but do not become really abundant until the Pinjor stage is reached. How frequently they may occur in the Tatrot stage is not known for that stage, like the Nagri, has yielded very few remains of Proboscidea hitherto. This is an obstacle to be overcome before one may say precisely when the migration from India to Europe took place, but actually it is not of major importance in the present instance, and for the following reason.

There is abundant proof (Schlesinger, 1922.) that *M. arvernensis* invaded Europe in post-Pontian times (*e.g.*, Levantine of Hungary); that it persisted until the Red Crag is proved by the presence in the British Museum of molars which retain their roots (regd. M7956). If it be shown at a later date that the stock first

became abundant in the Tatrot stage, then, by the same reasoning as that adopted hitherto, the migration to Europe may be considered as having taken place at that time. In such case, the Tatrot would be the equivalent of the Levantine and the Pinjor of the Villafranchian.

On the information generally available, and on much more which is in preparation for publication, the fossil Proboscidea indicate that the most probable correlation for the Indian and European deposits of the Middle and Upper Tertiary is

India	*Europe*
Pinjor	Villafranchian
Dhok Pathan	Pontian
Fatehjang	Burdigalian

Within this framework the other stages must be fitted, but the group I have been considering does not afford the information necessary for the attempt to be made here.

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A SEISMOLOGICAL STUDY OF THE BALUCHISTAN (QUETTA) EARTHQUAKE OF MAY 31, 1935. BY K. R. RAMANATHAN, M.A., D.Sc., AND S. M. MUKHERJI, M.Sc., *Colaba Observatory, Bombay.* (With plates 25 to 28.)

INTRODUCTION.

A preliminary account of the earthquake from the geological and general points of view has been published by Mr. W. D. West[1] in the Records of the Geological Survey of India. From the field evidence, Mr. West concluded that "in the case of the present earthquake there is no doubt about the position and extent of the epicentre, since severe damage was confined to a long narrow tract, away from which the intensity of the damage rapidly decreased. This tract extended from Baleli just north-west of Quetta through Dingar and Mastung to Mand-i-Haji and included the Shirinab Valley to the west of the Mastung-Kalat road. It is an area about 68 miles long and 16 miles wide. Within this area there were clearly places where the intensity was greater than elsewhere, notably Dingar and Mastung road and possibly Mand-i-Haji. Since it is well known that earthquakes are more severely felt on alluvium than on solid rock, it is possible that the length of the epicentral area as compared with its breadth has been enhanced to some extent by the fact that it is parallel to the valleys of the district." The surface crack extended from about 30°·3 N., 66°·9 E. to 29°·1 N., 66°·5 E., the centre of the region of maximum disturbance being 29°·7 N. and 66°·7 E. From the seismological evidence, the best position for the epicentre appears to be 29°·6 N., 66°·5 E., slightly to the south-west of the above position, but well within the region of maximum intensity.

The materials available for study.

The following materials were available for the seismological study of the present earthquake.

1. The seismograms (horizontal components only) of the Indian observatories: Bombay, Agra, Calcutta, Hyderabad and Kodaikanal.

[1] W. D. West, "Preliminary geological report of the Baluchistan (Quetta) Earthquake of May 31st, 1935." *Rec. Geol. Surv. Ind.*, LXIX, Pt. 2, p. 203, (1936).

2. The seismograms of 15 foreign observatories: Batavia, Chiufeng, Medan. Peichiko, Tokyo, Göttingen, Ivigtut, Pulkovo, Scoresby Sound, Vienna, Adelaide, Melbourne, Sydney, Ottawa and Tacubaya. These seismograms had been obtained from the Directors of the respective observatories by Dr. S. C. Roy and were kindly placed at our disposal for purposes of study.
3. The data of travel-times of the principal phases recorded at 142 observatories, as measured at the observatories themselves and mostly collected at Oxford for the purpose of the International Seismological Summary. These were obtained from Miss Bellamy by the Director of the Geological Survey of India and kindly sent to us. Some data were also taken from observatory bulletins.

The position of the epicentre and the time of origin of the earthquake.

For determining the epicentral time and position of the earthquake, only the arrival-times of the P phase at different observatories were used, as this phase is in general the least subject to uncertainty. As a first approximation, the centre of the region of greatest disturbance in Mr. West's map of isoseismals was assumed to be the epicentre. The distances of the different observatories from the assumed epicentre were calculated from the geographical co-ordinates and using Jeffreys' and Bullen's table of travel-times (published in 1934 in the International Seismological Summary for the year 1930), the times of arrival of P at the different places were calculated and compared with the observed times of arrival. A comparison of the mean residuals (observed minus calculated times) at observatories situated in different azimuths showed in what manner the hypothetical epicentre should be shifted in order to get a better fit and thus, by a process of successive approximation, the best position of the epicentre was determined and the corresponding epicentral time t_0 calculated. The distribution of stations in different directions is markedly non-uniform, the directions best represented being north-west and north-east. Towards the south, the number of stations is few, and even among them, the times of first onset as recorded at the Indian stations were abnormally

early. Table 1 shows the residuals P(O-C) at 40 selected stations and also the mean residuals in four different groups of these stations, arranged according to their direction from the focus. The assumed values of the epicentre for which figures are given are (i) 29°·7 N., 66°·7 E., which is very near the middle of the *inner region of maximum disturbance* marked in his map by Mr. West and *(ii)* 29°·6 N., 66°·5 E., the epicentre which is found to *fit the observations best.* The assumed value of t_0 or *epicentral time is 21h 32m 59s G.M.T.* It may be recalled that t_0 is not necessarily the actual time of the earthquake; it is the time "which makes t-t_0 at short distances proportional to the distance". If the focus is at the surface, the actual time of occurrence or the hypocentral time of the earthquake, according to Jeffreys, is about 5·8 secs. earlier than t_0.

TABLE 1.—*Comparison of Epicentres.*

P_1(O-C)—Epc. 29°·7 N., 66°·7 E. } P(O-C) calculated using geographical co-ordinates
P_2(O-C)—Epc. 29°·6 N., 66°·5 E. } and J. B. tables.

P_2^1(O-C)—Epc. 29°·6 N., 66°·5 E.—P(O-C) calculated with observed travel-times corrected for ellipticity (Bullen's tables) and using Jeffreys' revised tables (1937) of travel-times.

Station.	Azimuth.	Δ_1	P_1(O-C)	Δ_2	P_2(O-C)	P_2^1(O-C)
	°	°	secs.	°	secs.	secs.
Tashkent . .	6	11·8	1·3	11·9	0	0·1
Ekaterinburg .	352	27·5	0·3	27·55	—0·2	—0·4
Moscow . .	330	33·2	0·8	33·2	0·8	0·4
Helsingfors . .	329	41·2	0	41·2	0	1·0
Bergen . .	326	50·5	0·9	50·5	0·9	0·7
Scoresby Sd. . .	339	61·8	1·0	61·8	1·0	1·3
Ivigtut . .	334	75·1	—2·9	75·1	—2·9	—1·4
Mean of 7 stations.	NNE to NW		+0·2		—0·1	+0·2

TABLE 1.—*Comparison of Epicentres*—contd.

Station.	Azimuth.	Δ_1	P_1(O-C)	Δ_2	P_2(O-C)	P_2^1(O-C)
	°	°	secs.	°	secs.	secs.
Pulkovo	313	38·7	—0·9	38·7	—0·9	—0·2
Budapest	310	40·5	—2·1	40·4	—1·3	—0·7
Vienna	312	42·4	—1·9	42·3	—1·1	—0·4
Prague	313	43·9	—1·9	43·8	—1·1	—0·7
Jena	314	45·8	—2·1	45·7	—1·3	—0·8
Göttingen	314	46·9	—0·7	46·8	0	0·4
Stuttgart	312	47·2	—2·1	47·1	—1·3	—0·9
Strasbourg	311	48·1	—2·0	48·0	—1·2	—1·0
Besancon	309	49·3	—1·1	49·2	—0·3	—0·3
De Bilt	315	49·8	0·1	49·7	0·8	0·7
Uccle	313	50·3	—0·7	50·2	0·1	0
Paris	311	51·6	—0·5	51·5	0·3	0·1
Kew	315	53·2	—0·4	53·15	0	—0·3
Mean of 13 stations.	NW		—1·3		—0·6	—0·3
Helwan	278	30·6	—3·3	30·4	—1·5	—2·4
Athens	285	36·4	—3·2	36·2	—1·5	—1·9
Sofia	295	36·95	—0·5	36·8	1·3	1·5
Entebbe	234	44·05	—4·1	43·85	—2·5	—1·0
Algiers	296	52·75	—2·1	52·6	—1·1	—1·5
Almeria	297	57·0	—1·1	56·9	—0·4	—0·9
Granada	298	57·8	—0·9	57·7	0	—0·5
S. Fernando	298	60·1	—3·2	59·9	—1·8	—2·0
Cape Town	220	78·3	—2·7	78·1	—1·7	2·2
Mean of 9 stations.	NW to SW		—2·3		—0·8	—0·7

TABLE 1.—*Comparison of Epicentres*—concld.

Station.	Azimuth.	Δ_1	P_1(O-C)	Δ_2	P_2(O-C)	P_2^1(O-C)
	°	°	secs.	°	secs.	secs.
Calcutta . .	106	20·7	—0·2	20·85	—1·7	—1·7
Phu Lien . .	96	37·0	—0·4	37·2	—2·1	—2·0
Peichico . .	85	44·3	0·9	44·5	—0·7	—0·4
Manila . .	95	52·0	1·6	52·2	0·1	0
Nagasaki . .	70	53·3	1·9	53·5	0·4	0
Hukuoka . .	69	53·5	0·4	53·7	—1·1	—1·5
Tayooka . .	65	56·5	1·5	56·7	0·1	—0·4
Nagaya . .	65	58·3	2·6	58·5	1·2	1·0
Tokyo . .	64	60·35	1·2	60·55	—0·2	—0·1
Mizusawa . .	59	60·4	0·2	60·6	—1·6	—1·5
Amboina . .	109	67·55	0·2	67·7	—1·2	1·2
Mean of 11 stations.	NNE to ESE		0·9		—0·5	—0·5
Mean of 40 stations.			—0·7		—0·6	—0·4

The arcual distances Δ of the observatories from the epicentres in the above table have been obtained from the geographical co-ordinates and the calculated times of travel P_1(C) and P_2(C) taken from Jeffreys-Bullen tables. In the last column, the differences P_2^1(O-C) have been calculated correcting the observed travel-times for the ellipticity of the earth so as to give results as for the standard sphere (using Bullen's[1] "Tables for reduction of apparent travel-times of P and S seismic waves" and Jeffreys' revised tables of travel-times, 1937).[2] It will be seen that if we adopt as epicentre 29°·7 N., 66°·7 E., there is a considerable difference between the mean residuals from the westerly and easterly groups of observatories and that this difference practically vanishes if we adopt 29°·6 N., 66°·5 E. No appreciable effect is produced on the mean

[1] K. E. Bullen, "Tables for reduction of apparent travel-times of P and S seismic waves" *New Zealand J. Sc. and Tech.*, Vol. XIX, No. 1, pp. 47—54, (1937).
[2] H. Jeffreys, "Further corrections to P, S and SKS Tables" *M. N. R. A. S., Geoph. Suppl.* 4, No. 3, p. 242, (1937).

residuals by correcting for ellipticity although there are significant differences in individual residuals. From the magnitude of the residuals, it is clear that a correction of—0·5 sec. is necessary for t_o. The corrected value of t_o is $30^d\ 21^h\ 32^m\ 58{\cdot}5^s$ G.M.T.

The frequency distributions of P residuals in the two cases are shown in figs. 1 and 2.

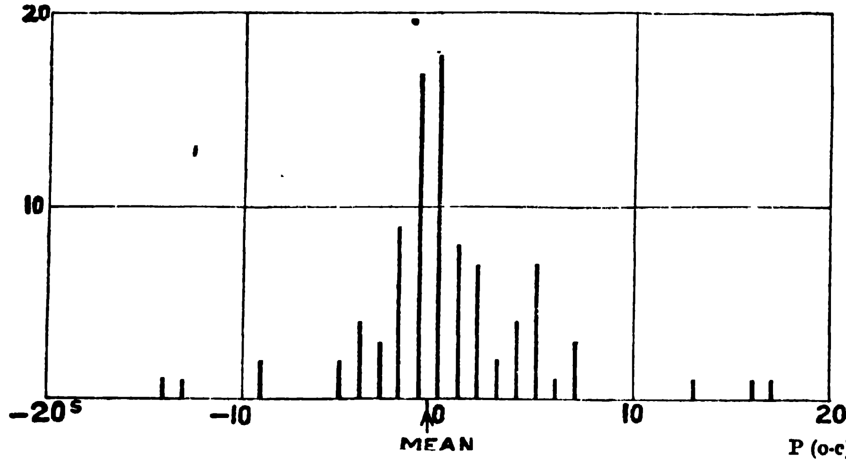

FIG. 1.—P residuals: (O-C) with t_0 assumed to be 21h 32m 59s and using J. B. tables.

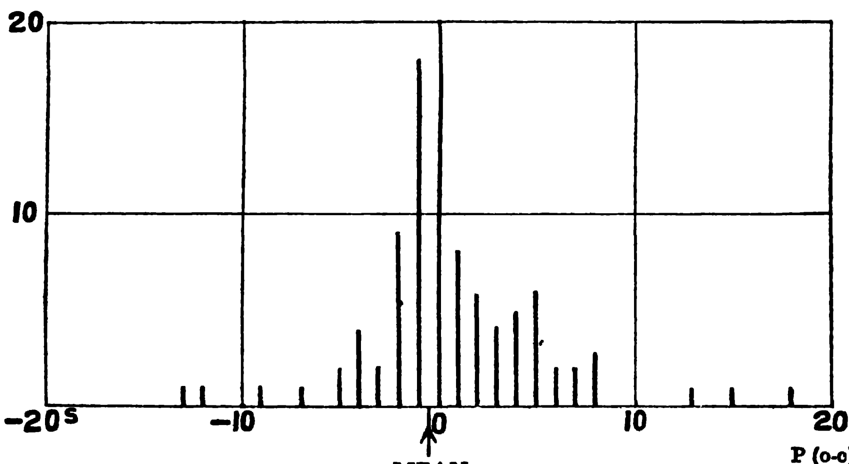

FIG. 2.—P residuals: (O-C) with t_0 assumed to be 21h 32m 59s and using J. B. tables with ellipticity correction.

Some noteworthy features of the seismograms.

The seismograms of this earthquake obtained at the Indian observatories are somewhat complicated. In the Agra Milne-Shaw record there is an impulsive beginning of a phase about 15s after the beginning of the first eP. In the Bombay seismograms, the following phases are recognisable :—

TABLE 2.

Phase.	Time. m	Time. s
eP_1	2	34
iP_2	2	50
iP_3	2	59
i	3	26
i*	3	46
i	4	04
iS_1	5	04
iS_2	5	20
iS_3	5	28

The phase i* marks the beginning of a series of long period oscillations superposed on the much more rapid oscillations usually characteristic of the preliminary phase at this distance. It perhaps corresponds to the beginning of P_g, though one would hardly have expected to see direct P_g at this distance (12°·1). In the seismograms of Hyderabad and Kodaikanal, one notices phases 16 sec. and 14 sec. respectively after the first incidence of disturbance. All these suggest that the shock was a multiple one, the first impulse being feeble and the second one marked iP_2 in Table 2, being the one recorded at the more distant stations. In this connection, reference may be made to the following observations made by Mr. West (*loc. cit.*, p. 212). "At least five to ten seconds before the main shock started, a small tremor was felt which was sufficiently strong to be recognized as an earthquake." This was at a place about four miles north of Quetta. At Quetta itself, "a sentry on duty on top of the Ammunition Depot noticed a shake

which he considered to have occurred at least half a minute before the main movement." It must be mentioned, however, that in Calcutta seismograms, there is no evidence of an earlier weak disturbance.

The seismograms of the Indian stations and also of the foreign observatories showed that the amplitudes increased gradually, interrupted by larger and larger impulses and that the surface waves were very large compared with the preliminaries. (Plates 25, 26, 27 and 28).

These features, according to Gutenberg and Richter[1], are suggestive "of extended faulting or more probably, block movement." According to this view, the earthquake was the result not of an instantaneous process but took comparatively longer time during which long-period vibrations were set up, which disturbed the usual short-period waves.

The depth of focus of the earthquake.

The depth of focus of an earthquake to which the normal international tables (Jeffreys-Bullen) apply is not known with exactness but a recent estimate by Jeffreys[2] makes it about 10 km. The destructive nature of the Quetta earthquake and the fact that the long-wave phases in the seismograms were exceptionally well-developed show that the depth of focus of this earthquake was smaller than normal. Seismograms at near observatories (distance less than 10°) with good time-determinations are necessary if the depth of focus of a shallow earthquake is to be determined with any accuracy; in their absence, we have to examine whether any conclusion can be drawn from the "Z phenomenon" or the deviations of S-P residuals from those of a normal earthquake. If the mean value of the residual is positive (this is usually not very different at different distances), the presumption is that the earthquake was shallower than normal. Jeffreys is of opinion that +3 seconds is the maximum possible value of Z, which would occur if the focus

[1] B. Gutenberg and C. F. Richter "On Seismic Waves" (First Paper), *Gerl. Beitr. zur Geoph.*, Vol. 43, p. 73, (1934).

[2] H. Jeffreys, "Further corrections to P, S and SKS Tables" *M. N. R. A. S., Geoph. Suppl.* 4, No. 3, p. 242, (1937).

were at the surface. In a few earthquakes such as the Santa Barbara earthquake of 1925 June 29, and the African Rift Valley earthquake of 1928 June 6, larger values of Z (+8 and +10 seconds respectively) have been obtained but these large values have been explained as being due to possible late reading of the S phase in the former earthquake and to the possible occurrence of two successive shocks within a few seconds of each other in the latter.[1] In the present earthquake, the mean value of Z comes to +5·9 seconds, if we exclude those values of S-P which deviated more than ±15 secs. from the mean. The number of observatories at which the times of arrival of the waves fulfilled this condition was 72. Of these, 56 observatories lay within the range of distance 40° to 60°. The mean residual S-P for these 56 stations alone was +6·1 secs. This large positive value of Z greatly exceeds the maximum of 3 seconds suggested by Jeffreys for a surface focus. To see whether part of the discrepancy might be due to the fact that no correction was made to the travel-times for the ellipticity of the earth, S-P residuals were calculated after applying all the necessary corrections for ellipticity and using Jeffreys' new tables of travel-times of P and S for a *continental surface-focus*[2]. The mean S-P residual was now changed to +3·2 seconds considering all the 72 stations and to +3·7 seconds considering only the stations lying in the range 40° to 60°. There is no large alteration in the nature of the distribution of the residuals about the mean (Figs. 3 and 4). The change

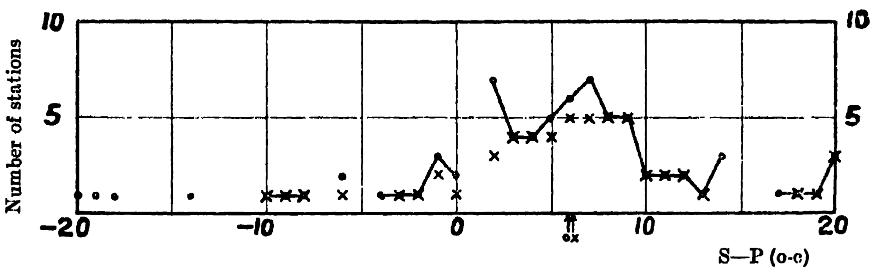

FIG. 3.—"S-P" residuals using normal J. B. table. t_0 assumed to be 32m 59s. • • • • • • • • All stations; × × × × stations between 40° and 60°.

[1] E. Tillotson, "The African Rift Valley Earthquake of 1928 January 6" *M. N. R. A. S. Geoph. Suppl.* 4, No. 1, p. 92, (1937).
E. Tillotson "Further note on the African Rift Valley Earthquake of 1928 January 6," *M. N. R. A. S. Geoph. Suppl.* 4, No. 4, p. 315 (1938).
[2] H. Jeffreys, *Loc. cit.*

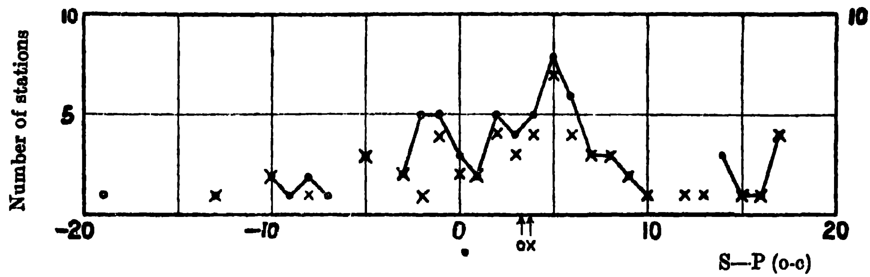

FIG. 4.—" S-P " residuals using Jeffreys' ' continental surface focus table.' t_0 assumed to be 32m 59 s. • • • • • • • • All stations ; × × × × stations between 40° and 60°.

of residual from +5·9 secs. to +3·2 secs. points to a position of the focus nearer the surface than that of a normal earthquake. There still remains too large a mean residual S-P to be attributed to accidental error. Figs. 3 and 4 show that there are two prominent peaks in the curve of residuals which are separated from each other by an interval of about 6 secs. It is probable that these features are a consequence of the fact that the shock was not a simple one originating within a small area at a definite instant, but was the result of a comparatively protracted process.

The energy of the earthquake.

To estimate the energy of an earthquake, various methods have been used. When the earthquake is shallow, most of the energy is in the form of long waves, and an estimate of the energy of these waves will therefore give a lower limit for the energy of the earthquake. We use the following simple relation which has often been used for this purpose.

E=Mean energy per unit volume $\times 2\pi$ R sin $\triangle \times$ thickness of layer in which the long waves travel $\times$ length of wave-train.

$$=4\,\pi^3\,\rho\,R\,\sin\,\triangle \int \frac{a^2\,HV}{T^2}\,dt.^*$$

*The numerical factor 8 is often used instead of 4 in this expression. Since the mean energy during an oscillation, which is partly kinetic and partly potential is equal to the maximum kinetic energy, its value per unit volume is $\frac{\frac{1}{2}\,\rho \times 4\pi^2 a^2}{T^2}$. This multiplied by $2\,\pi$ R sin $\triangle$ gives only $\frac{4\,\pi^3 \rho a^2\ R\ \sin\ \triangle}{T^2}$.

where E is the energy conveyed by the long waves,

ρ the density of the surface layer of the earth ($\doteqdot 3$ gm/c.c.),
$\triangle$ the angular distance of the observing station from the source,
H the thickness of the layer,
a the amplitude of the waves,
T their period,

and V the velocity of the waves ($\doteqdot 3\cdot 5\times 10^5$ cm/sec.). There can be some doubt as to what value of H should be adopted. If it is taken as the depth of penetration of Rayleigh waves, $H=\frac{7\cdot 06\lambda}{2\pi}=1\cdot 12\lambda$ according to Jeffreys, provided **a** is now taken to be the horizontal displacement. When the period of the waves is 10 to 12 sec., this depth is about 43 km. For a similar calculation, Tillotson[1] used for H the thickness of the granitic layer assuming it to be 13 km. We shall adopt a value of 15 km. in our calculation.

Putting in the appropriate numerical values for the Quetta earthquake as recorded at Bombay, $\triangle=1340$ km., T=10 to 12 sec. and H the assumed thickness of the granitic layer=$1\cdot 5\times 10^6$ cm. In the EW seismogram at Bombay, some of the excursions of the spot of light went outside the paper and one can therefore obtain only a lower limit to the energy of the waves. The integral $\int\frac{a^2dt}{T^2}$ evaluated from the EW seismogram comes to be about 5×10^{-3} cm²/sec. In the NS component record also, the vibrations have been apparently obstructed on one side and we can only say that the value of the integral should have been greater than 5×10^{-3} cm²/sec. According to Rayleigh's theory of surface-waves, the amplitude of vertical movement should be about 1·5 times that of the horizontal in the direction of propagation. Actually the observed proportion is often different from this and in the absence of a vertical component seismogram, the value of $\int\frac{a^2dt}{T^2}$ corresponding to the vertical component has been assumed to be about 5×10^{-3} cm²/sec. The total value of $\int\frac{a^2dt}{T^2}$ from all the three

[1] E. Tillotson, "On an earthquake near Imotski," *M. N. R. A. S.*, 2, 8, p. 426, (1931).

components is therefore greater than $1 \cdot 5 \times 10^{-2}$ cm^2/sec. and the computed energy of the long waves of the earthquake greater than $3 \cdot 2 \times 10^{20}$ ergs. In a similar way, computing from the only available (E-W) component at Kodaikanal in South India and multiplying by 3, the energy of the long waves there was found to be $1 \cdot 5 \times 10^{21}$ ergs.

From the Göttingen ($\triangle = 46^\circ \cdot 8$) records, the energy of the long waves in the different components was computed to be as follows :—

Component.	Computed energy in ergs.
N-S	$1 \cdot 1 \times 10^{20}$
E-W	$1 \cdot 4 \times 10^{20}$
Z	$0 \cdot 9 \times 10^{20}$
Total	$3 \cdot 4 \times 10^{20}$

No doubt there are considerable differences in the recorded amplitudes depending on the crustal structure at the recording station but the above values nevertheless give an approximate idea of the energy of the earthquake; it is clear that the energy must have been of the order of 10^{21} ergs.

(2) An attempt has been recently made by the Pasadena seismologists[1] to introduce an instrumental magnitude scale for earthquakes. The scale is logarithmic and is based on the measured maximum amplitudes in the recorded traces of the shock in a standard seismograph. If the maximum amplitudes due to two similar earthquakes recorded at the same distance are in the ratio 10^m : 1, the magnitude of the first shock is said to exceed that of the second by m. When the seismographs are situated at different distances and are of different makes, even then the traces can be made use of to give an idea of the magnitude of the quake if the ground amplitude can be deduced from the trace. The equation connecting the maximum ground amplitude and the magnitude is (1) $M = \log a - \log A_0 - 2 \cdot 5$ where M is the magnitude of the earthquake, 'a' is the maximum recorded ground amplitude and A_0 is a constant depending on the distance of the station from the earthquake centre, being the maximum amplitude in millimetres

[1] B. Gutenberg and C. F. Richter "On Seismic Waves" (Third Paper), *Gerl. Beitr. zur Geoph.*, Vol. 47, p. 119, (1936).

in the recorded trace of a standard torsion seismometer by a shock of magnitude 0. Gutenberg and Richter have drawn a curve showing the relation between A_o and $\triangle$ and we extract below for convenience a small table showing this relation.

TABLE 3.

Distances in degrees. $\triangle$	log A_o
1	—3·1
2·5	—4·0
5	—5·0
10	—5·8
20	—6·5
45	—7·0
100	—7·5
150	—8·0

The energy of the earthquake E being proportional to the square of the amplitude the relation between energy and magnitude is expressed by the relation

$$\log E - \log E_o = 2M$$

where E_o is the energy of an earthquake of magnitude 0.

The following table gives the recorded maximum horizontal ground movements at a few observatories due to the Quetta earthquake and the corresponding calculated values of the magnitude.

TABLE 4.

Station.	$\triangle$	Maximum horizontal amplitude.	M
	°	μ	
Budapest	40·4	614	7·2
Zagreb	42·3	756	7·4
Hongkong	45·2	c.400	7·1
Barcelona	52·5	580	7·5
Kew	53·1	>450	>7·4
S. Fernando	59·9	250	7·1
Melbourne	99·5	157	7·2
			7·3

Taking 7·3 to be the magnitude of the earthquake, its energy E is given by

$$\log E = 14{\cdot}6 + \log E_o$$

To determine E absolutely, we require to know E_o the energy of a shock of magnitude 0. This was first estimated by Richter to be 10^6 ergs, but was later modified by Gutenberg and Richter to 10^7 to 10^8 ergs. Taking E_o to be 10^7 ergs, $E = 4{\cdot}0 \times 10^{21}$ ergs.

(3) We can also determine the approximate energy of the earthquake from the area over which the shock was felt. Assuming from his Pasadena experience that the lower limit of perceptibility of an earthquake corresponds to an acceleration of 250 milligals (0·25 cm/sec^2) or a recorded maximum amplitude of 5 mm. in the seismogram of a standard torsion seismometer, Richter[1] gives the following table showing the relation between the radius of the felt area and the magnitude of the earthquake.

TABLE 5.

Mean radius of felt area (km.) .	150	250	360	530	770	1,060
Magnitude	5·0	5·5	6·0	6·5	7·0	7·5

According to West, the area over which the Quetta earthquake was felt was approximately 105,000 sq. miles and its mean radius is therefore 295 km. According to above table, the magnitude would only be 5·7 which is obviously too low. It is probable, as West has pointed out, that owing to the fact that the earthquake occurred at night when people were asleep it was not felt over as wide an area as it would have been during daytime.

Remembering the fact that the energies of the most intense earthquakes such as the Assam earthquake of 1897 have been estimated to be above 10^{25} ergs, the present earthquake had less than $\frac{1}{2000}$ as much energy as the most intense shocks recorded in recent years.

[1] C. F. Richter, "An Instrumental Earthquake Magnitude Scale," *Bull. Seism. Soc. Amer.*, Vol. 25, No. 1, p. 18, (1935).

The times of travel of the different phases as recorded at the various observatories are given in a collected form in table 6.

TABLE

Epicentre : 29°·6 N. 66°·5 E.
T_0 : 1935 May 30—21h 32m 58·5 s. G. M. T.

Station.	Δ	Comp.	P	P (O-C) J. B.	P (O-C) J. (1937).	Comp.	S	S (O-C)
	°		m. s.	s.	s.		m. s.	s.
Samarkand	9·0		?				e 4 21	10
Dehra Dun	10·0	N	2 51 ?	30			4 21	8
Agra	10·45	E	i 2 12	—15	—15		i 4 02	—21
		E	i 2 27	0	0		i 4 17	—6
Andijan	11·5		?				e 3 24	
Tashkent	11·9		i 2 47	0	0			
Bombay	12·1	N, E	i 2 34	—16	—15		5 04 ?	—1
		N, E	i 2 50	0	1		5- 20 ?	15
			i 2 59	9	9			
Hyderabad	16·3		i 3 29	—16	—15		i 6 44	—2
			i 3 41	—4	—3			
			i 3 45	0	1			
Baku	17·3		i 4 03	5	5			
Calcutta	20·85	E	i 4 37	—2	—2	N, E	8 00	—15
							8 24	0
Tiflis	21·3		i 4 46	2	3		i 8 43	10
Kodaikanal	21·9	E	i 4 38	—12	—11	E	i 8 36	—8
		E	i 4 52	2	3			
Ksara	26·3		i 5 31	—1	—1		10 10	7
Ekaterinburg	27·55		i 5 43	0	0		i 10 29	5
Yalta	29·5		6 01	0	—1		11 10	14
Simferpol	29·7		6 03	1	0		11 14	15
Sebastopol	30·0		6 05	0	—1		11 17	13
Helwan	30·4		6 07	—2	—3		i 11 48	38
Moskow	33·2		e 6 34	1	0		12 00	6
Bucarest	35·0		e 6 54	5	4		13 01	40
Athens	36·2		6 58	—1	—2		12 30	0
Sofia	36·8		e 7 06	2	1			
Phu Lien	37·2		e 7 06	—2	—2		e 12 19	—35
Lemberg	37·7	E	e 7 25	13	13	E	e 13 34	32
		N	e 7 28	16	16	E	e 13 49	47
Pulkovo	38·7	N, E, Z	i 7 22	1	2		e 13 22	5
Belgrade	39·1		e 7 24	0	0			
			7 25	1	1			

6.

	PP	PPP	Pc P		SS	SSS		L	M		Other phases and remarks.
	m. s.	m. s.	m. s.		m. s.	m. s.		m.	m.		
											Pn or P* ? ? 14 m 00 s.
								5·1	5·9		First movement towards E.
											Sn or P* ? ? 13 m 01 s.
								5·9	6·3		i 5m 42s; first movement towards E and S.
					6 59			8·4			i 3m 53s; ? 3m 49s.
	4 53		8 30		8 49			10·2	11·6		i 8m 32s; first movement towards E.
	5 10										
	i 4 57				8 57			10·5	19·5		i 9m 18s, 13m 10s; (?) 11m 45s.
	5 03				9 16			10·6	11·9		i 5m 10s; 8m 57s (Pc P ?)
		7 13			12 49				22·0		
									23·5		
									22·0		
								e 20·1	25·7		
								e 20·9	31·5		
	i 8 51		i 9 31					18·5	23·5		
								20·0			
								i 19·3	21·6		i 11m 42s, 14m 27s; 16m 56s (SSS ?); ? 28m 13s.
								19·6			

TABLE

Station.	Δ	Comp	P	P (O-C) J. B.	P (O-C) J. (1937).	Comp	S	S (O-C).		PP	PPP	Pc P
	°		m. s.	s.	s.		m. s.	s.		m. s.	m. s.	m. s.
Medan . . .	40·05		7 49	17	18		14 04	27				
Budapest . .	40·4		7 34	—1	—1		14 12	30				
Helsingfors . .	41·2		*i* 7 42	—1	1		14 02	8				
Tarente . . .	41·2		7 28	—14	—13		14 36	42				
Konigsberg . .	41·3		*e* 7 48	5	6		14 08	13		9 11	9 41	
Chiufong . .	41·5		*e* 7 49	4	5		*e* 13 56	—2				*i* 9 36
							i 14 12	14				
Vienna . . .	42·3		*i* 7 50	—1	0		14 14	4		9 24	10 08	*i* 9 34
Zagreb . . .	42·3		*e* 7 50	—1	—1		14 39	29		9 32		
Hongkong . .	43·2		7 53	—5	—5		14 21	—3		9 30	9 59	
Laibach . . .	43·3		*e* 8 01	2	2		*i* 15 01	36				
Prague . . .	43·8		8 02	—1	—1		*e* 15 05	32				
Trieste . . .	43·85		*e*, *i* 8 02	—1	—1		*i* 14 40	6				
Entebbe . . .	43·85		8 01	—3	—1		14 33	—1				
Peichico . . .	44·5	N, E, Z	*i* 8 08	0	0	N, E, Z	14 50	7		9 44	10 20	9 32
										9 56		
Treviso . . .	44·95		*i* 8 17	5	5		*i* 15 01	11				
Cheb . . .	45·1		*e* 8 19	5	6		*e* 15 01	10				
							e 15 31	40				
Padova . . .	45·2		8 12	—2	—2		14 50	—3				
Florence . . .	45·6		*i* 8 22	5	5		15 01	·8				
Prato . . .	45·7		*i* 8 22	4	1		14 53	—7				
Jena . . .	45·7		*e* 8 17	—1	—1		15 01	1				
Gottingen . .	46·8	E, Z	*i* 8 27	0	1	N, E	*i* 15 17	1		10 25		9 38
			m 8 34	7	7		*i* 15 22	6				
			e 8 36	9	9		*e* 15 24	8				
Chur . . .	46·8		*e* 8 25	—2	—2		15 33	17				
Hamburg . .	47·0		*e* 8 28	—1	0		15 20	1				
Tunis . . .	47·0		*i* 8 25	7	7							
Stuttgart . .	47·1		*e* 8 28	—1	—1		*i* 15 13	—7				

6—*contd.*

	PS	SS	SSS		G	L	M		Other phases and remarks.
	m. s.	m. s.	m. s		m. s.	m.	m.		
						i 19·5 20·8	22·8		*i* 10m 41s.
					17 0		25·0		
	14 31		17 31						*i* 14m 36s, 16m 26s : *e* 18m 18s.
		i 16 46				*i* 20·1 *i* 20·4	24·3 25·7		*i* Sc S 17m 48s.
		17 21			17 11	19·5 20·7	33·0		*i* 8m 26s ; PcS 13m 28s ScS 17m 54s. Compression.
						21·4	29·6		*e* PPPP 10m 31s ; *i* 12m 04s ; *e* 7m 56s, 8m 36s, 9m 05s, 12m 19s ; ScS 18m 27s ; 18m 20s, 19m 23s.
						20·9	26·5		10m 51s, 12m 38s ; 31·2m.
						24·1	30·0		*i* 10m 40s, 12m 15s.
						19·0	33·5		*e* SSS ? 18m 15s.
	i 15 20 15 43		18 50			21·0 21·6	30·5		Sc S 18m 03s ; *i* 8m 53s, 10m 52s, 12m 08s, 10m 45s, 11m 31s, 12m 58s : 19m 33s, 15m 05s.
							27·0		
		17 26	18 44			*i* 21·3	26·3 31·1		*i* 8m 26s, 8m 32s, 15m 08s, Compression
						26·0	29·5		
		18 07				21·0	29·5		*e* 9m 01s, 11m 17s 15m 35s : *i* 10m 41s.
	15 52	18 42			19 07 19 12	21·8 22·3	30·0		*i* 9m 25s Compression.
	15 56	*e* 19 20				22·3 23·0	29·0		
									16m 50s.
						30·0			*i* 9m 18s ; *e* 13m 31s, 22m 20s.

TABLE

Station.	Δ	Comp.	P	P (O-C) J. B.	P (O-C) J. (1937).	Comp.	S	S (O-C)		PP	PPP	Pc P
	°		m. s.	s.	s.		m. s.	s.		m. s.	m. s.	m. s.
Zurich . . .	47·45		e 8 31	—1	—1		e 15 44	19				
Karlsruhe . .	47·6		i 8 38	5	5		e 15 41	14				
Strasbourg . .	48·0		8 35	—1	—1		i 15 29	—4				
Basel . . .	48·2		e 8 37	—1	—1							
Taihoku . . .	48·6		8 39	—2	—2		15 51	10				
Newchatel . .	48·6		e 8 37	—4	—4		e 16 02	21				
Besanca . . .	49·2		e 8 45	0	0		e 15 31	—19				
De Bilt . . .	49·75		8 50	1	0		16 07	10				
Jinsen . . .	49·9		e 8 42	—9	—9		i 16 04	1				
Marseilles . .	49·9		8 23	—28	—28		16 03	3				
Uccle . . .	50·24		8 53	0	0		16 13	9			11 08	
			8 54	1	1							
Bergen . . .	50·5		i 8 56	1	1		16 13	5			11 45	
Lille . . .	51·1		e 9 04	3	4		16 50	34				
Paris . . .	51·5		i 9 03	0	0	E	16 14	—7				
Tannanarive . .	51·8		e 8 56	—9	—7		16 16	— 9				
Manila . . .	52·2	E, Z	i 9 08	0	0	N, E	16 50	21				
Barcelona . .	52·5		9 09	—1	—2		16 40	5		11 05		
Algiers . . .	52·6		i 9 10	—1	—1		i 16 41	5				
Batavia . . .	52·7	Z	e 9 19	7	8		16 48	10				
Kew . . .	53·15	Z	i 9 15	0	0	N, E	i 16 52	8				Z 10 24
							17 06	22				
Nagasaki . .	53·5		9 18	0	0							
Hukuoka . .	53·7		9 18	—1	—2		16 56	4				
			9 20	1	0		17 00	8				
Oxford . . .	53·7		9 23	4	4		17 02	10				
Durham . . .	53·8		9 27	7	7		16 57	4				
Tortosa . . .	53·8		i 9 16	—4	—4		17 01	8				

6—*contd.*

	PS	SS	SSS		G	L	M		Other phases and remarks.
	m. s.	m s.	m. s.		m s.	m.	m.		
						26·3	31·0		
						22·0	31·0		
		19 26				26·1			Assumed —30s as time correction.
						22·0			
						28·3	31·9		SS (?) 19m 55s.
					21 01				
	16 42					25·0	32·1		*i* 12m 09s, 13m 22s, 17m 03s.
						24·3	35·0		*i* 13m 19s.
						27·0			
	16 52					25·0	32·0		
						26·2	30·7		
	17 05					23·1	29·8		
					22 01 ?		33·0		
						26·7	30·7		*i* ScS 18m 49s. Beginning uncertain due to microseisms.
						27·0			
					21 50	26·0	39·2		*i* 9m 20s, 12m 21s, 17m 14s, 17m 23s, 20m 50s, 21m 36s, 24m 12s. Dilatation.
							30·6		PPP (?) 12m 37s ? 21m 02s.
						26·7	30·9		? 21m 02s
							33·9		
	17 26						33·0		
									? 23m 33s.

TABLE

Station.	Δ	Comp.	P	P (O-C) J. B.	P (O-C) J. (1937).	Comp.	S	S (O-C)		PP	PPP	Pc P
	°		m. s.	s.	s.		m. s.	s.		m s.	m. s.	m. s
Stonyhurst	54·85		9 26	2	2		17 02	2				
Edinburgh	54·7		*i* 9 27	1	0		*i* 17 12	7				
Liverpool	54·7		*i* 9 31	5	4		*i* 17 11	6				
Alicante	55·0		*e* 9 31	2	2		*i* 17 29	20		11 41	12 44	
			i 9 36	7	7							
Rathfarnham Castle	56·65		*i* 9 43	2	2		*i* 17 41	10				
Toyooka	56·7	Z	9 41	0	0	N	17 42	10				
		E	9 43	2	2	E	17 44	12				
		N	9 46	5	5	Z	17 46	14				
Almeria	56·9		*i* 9 42	0	—1		*i* 17 48	13		11 57		
Sumoto	57·1	N	9 39	—5	—5	N	17 44	7				
		E, Z	*i* 9 44	0	—1	Z	17 45	8				
						E	17 46	9				
Kobe	57·25	Z	*e* 9 42	—3	—3	N, Z	17 41	2			13 07	10 36
		N, E	*e* 9 45	0	0	E	17 42	3				
							17 54	15				
							18 02	23				
							18 03	24				
Toledo	57·4		*e* 9 42	—4	—4		17 43	2		11 58		
			i 9 46	0	—1					12 10		
Granada	57·7		*i* 9 48	0	—1		*i* 17 49	3		12 21		10 45
Malaga	58·45		9 50	—4	—4		18 00	4		12 14		
							18 17	21				
Nagaya	58·5		9 55	1	1		18 04	8				
Sanfernando	59·9	Z	*i* 10 02	—2	—2	E	*i* 18 36	21			*i* 13 24	
			10 04	0	0		*i* 18 37	22				
Serrado Pilar	60·4		10 05	—3	—2		18 20	—1				
Tokyo	60·55	N, E	*e* 10 08	0	0	N	18 27	4				
Mizusawa	60·6		*e* 10 07	—2	—2		18 38	14				
Coimbra	60·6		*e* 9 56	—13	—12		18 14	—10				
Scoresby Sund	61·8	Z	*i* 10 18	1	1		18 40	14		12 31		10 58
							i 18 53	27				
Amboina	67·7		10 55	—1	1		19 46	—7				

6—*contd.*

	PS	SS	SSS		G	L	M		Other phases and remarks.
	m. s	m. s.	m. s.		m. s.	m.	m.		
		21 13			? 22 15	26·0	35·0		i 17m 17s ; Sc S 19m 14s.
					? 22 25		36·0		
						28·6			
						26·5	31·1		
					? 22 47		34·8		
							38·5		
		21 46			? 22 56	e 26·6	56·3		
							32·8		
							37·8		
					?e22 41		35·7		i 10m 14s, 18m 35s, 20m 07s, 22m 31s, 29m 09s.
							37·5		
							38·0		
							39·5		
	18 13				? 22 55		54·6		
						28·4	46·5		
		21 56	24 20			28·4			? 11m 12s; e 26m 22s ; ScS (?) 20m 05s.
					23 35		35·2		? 11m 22s.
					? 25 02	29·0	32·0		PcP (?) 10 32; ? 23m 06s, Dilatation.
						28·0			
						28·0	33·5		
						31·6			
	19 13	22 41	25 14		25 54	i 29·6	33·7		e 14m 55s. Dilatation.
						30·0	34·8		
						31·0			
						36·0			

TABLE

Station.	Δ	Comp.	P	P (O-C) J. B.	P (O-C) J. (1937.)	Comp.	S	S (O-C).	PP	PPP	PKP	PKKP
	°		m. s.	s.	s.	'	m. s.	s.	m. s.	m. s.	m. s.	m. s.
Ivigtut . .	75·1	Z	e 11 38	—3	—1		21 23	2				
Perth . .	77·3						21 36	—10	14 51			
Cape Town .	78·1		11 56	—2	2		21 34	—21				
Sitka . .	91·4		e 13 07	3	4		i 24 12	3	e 16 15	18 42		
			e 13 26	22	23							
Halifax .	93·0		e 13 13	2	3		24 12	—12	16 49			
Adelaide . .	93·6											
Burlington .	97·3		13 38	7	8		25 31	28	18 11			
			13 40	9	10							
Ottawa . .	97·5		e 13 39	7	8				17 25	19 31		
Saskatoon .	98·05		13 49	15	15							
Oak Ridge .	98·15		i 13 39	4	5		25 11	1	17 19			
Weston .	98·3											
Melbourne .	99·5						25 11	--12				
Ithaca . .	100·3								e 18 31			
Toronto .	100·35		e 13 56	11								
Buffalo . .	100·8		e 13 48	1					e 17 49	? 20 21		
Victoria. .	101·5		14 09	18								
Philadelphia .	101·9		14 05	12			25 36	—7	17 49			
			14 15	22					18 06			
Riverview .	102·0						? 25 26	—18	18 13			
Sydney . .	102·0								18 19			
Pennsylvania .	102·25							[14]				

6—*contd.*

	SKS	SKKS	PS	PPS	SS	SSS	G	L	M		Other phases and remarks.
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m.	m.		
			22 15		26 25	29 54	30·6	N, E,Z *i* 35·9	41·2		Compression.
								Z *e* 36·5			
			22 01		26 01			36·0	56·3		Assumed clock correction of +4m.
								36·6	43·5		
	i 23 43				*e* 30 45		37 28	*e* 45·3			
								e 45·5			
								45·0			SS (?) 29m 55s *i* 27m 09s.
	i 23 38		*e* 25 19			? 34 09	39·4	45·3			
	24 31				32 01			44·9			
								47·7			
	i 24 33				31 25		? 39 25	47·0			*e* 42m. 13s.
	24 17				32 01			47·0			
	24 37										
	i 24 36								53·1		34m 01s.
	e 24 14					36 21	41·0	44·0	55·5		*i* 24m 39s, 27m 54s, 29m 35s, 44m 38s, 45m 47s.
								47·2	60·0		
								50·1			
	24 25										*e* 27m 13s.
	24 49										
	24 30		27 04					48·8			
			i 26 43	*e* 27 29							*e* 22m 25s.
		i 24 58						42 08	60·6		
	24 31		27 07		33 16			48·0			*e* 20m 48s.
	24 48				33 17						
	25 01							? 44·4	66·7		
								49·6	67·3		*i* 29m 31s.
	i 24 50							50·0	63·3		*i* 31m 31s, 33m 13s.

TABLE

Station.	Δ	Comp.	P	P (O-C) J. B.	P (O-C) J. (1937.)	Comp.	S	S (O-C).	PP	PPP	PKP	PKKP
	°		m. s.	s.	s.		m. s.	s.	m. s.	m. s.	m. s.	m. s.
Seattle . .	102·35							[-5]	18 09			
Pittsburg .	103·4		e 14 29	30				[—12]	e 18 13	20 26		
Georgetown .	103·55		e 14 00	0				[—6]	e 18 15	20 51		
Bozeman .	104·7								e 18 23			29 49
Chicago .	104·7			[—12]				[—5]	18 24		e 17 49	?30 09
								[—37]				
Charlottes Ville	104·9							[—7]	e 18 18			
								[-5]				
Florissant .	108·3	Z	e 14 22	—1		N	i 26 22	[—9]	i 18 52			i 29 48
St. Louis .	108·4		e 18 46	23		N, E	i 26 27	[—7]				e 29 46
Columbia .	109·4							[15]	e 19 11			
Denver . .	110·3							[—19]		e 21 30		
Ukiah . .	110·7						27 17		e 19 21			
Berkeley .	112·0		e, i 14 48	8			i 27 07		i 19 04	i 22 07		
			i 14 50	10			27 42					
							e,i 27 44					
Little Rock .	112·6			[6]		E	e 27 06	[—10]	e 19 14	21 43	N18 32	
							e 27 09	[—7]	e 19 15	e21 45	e18 35	
Tinemaha .	113·2			[7]					e 19 31		e18 35	e 29 30
Honolulu .	113·4						27 03		20 09	22 15		
							27 14		e 20 13			
San Juan .	113·8			[+7]				[17]	e 20 13		18 36	
Pasadena .	116·1			[13]		Z	e 27 50	[—1]	i19 48	e22 21	Ze18 48	e29 20
											18 50	
Loyola . .	116·4								?e18 07			
Tucson . .	118·1								e 20 01			
Christ Church	121·0		15 27	[8]				[0]			18 56	

6—*contd.*

Comp.	SKS	SKKS	PS	PPS	SS	SSS	G	L	M		Other phases and remarks.
	m. s.	m. s.	m. s.	m. s	m. s.	m. s.	m. s.	m.	s.		
	24 32						? 41 22	53·6			*e* 43m 09s.
	i 24 30		27 26					48·5			? 34m 14s.
	24 37		27 12	28 14	33 30			48·5			
					i 33 32			49·0			
		? 25 18			*e* 33 23		? 42 31	50·0			*e* 26m 52s.
	24 44			*i* 28 04	*e* 33 34			? 46·0			*i* 34 04, 41m 57s ; *e* 17s, 30s, 36m 27s.
	24 46										
	24 42		27 37		33 22			48·3			Sc S Sc S 38m 18s ; *e* 41m 06s ; ? 44m 26s.
	24 44				*e* 34 06						
	e 24 57	?*i* 25 22	*e* 27 57	*e* 28 56		*i* 38 16		*i* 51·3	*i* 56·8		
	e 24 57	? 25 22	*e* 27 58		*e* 34 08	*e* 38 16		*e* 51·4	56·8		
	25 26		*e* 28 34	*e* 29 41				50·9			*e* 23m 14s, 31m 43s, 35 m 31s, 35m 44s.
	e 24 56		*e* 28 26	*e* 29 30				? 44·0	58·8		*e* PSPS 35m 09s ; *e* 26m 15s, 38m 40s ; *i* 30m 05s.
			i 29 06		34 26	*e* 39 01	45 15				*e* 22m 21s, 23m 27s.
			29 04		35 06						
		26 12									Assumed -4m 30s as time correction.
N, E	*e* 25 14	*e*26 07	*e*28 54	*e* 29 52	35 06			53·0	62·0		
N, E	*e* 25 17	*e*26 24		*e* 30 05	35 15			*e* 53·1	*e* 62·2		
			?*e*29 25		*e* 35 35			? 49·7			PSPS (?) 36m 05s ; *i* 37m 41s, 37m 53s.
					35 41			49·9			
	e 25 46	27 19		*e* 30 18				? 49·0			*e* PSPS 36m 16s ; *i* 43m 21s ; e 20m 19s, 37m 01s. Assumed +1m as time correction.
								51·2			
	e 25 36		*i* 29 26	*e* 31 01				49·9			*i* 19m 34s.
							?*i*48 37		61·9		*e* 28m 37s, 37m 58s.
			29 19					50·1			? 41m 28s.
	25 53		30 11						65·8		Assumed—5m 45s as time correction.

TABLE

Station.	Δ	Comp.	P	P (O-C) J. B.	P. (O-C) J (1937.)	Comp.	S	S (O-C).	PP	PPP	PKP	PKKP
	°		m. s.	s.	s.		m. s.	s.	m. s.	m. s.	m. s.	m. s.
New Plymouth	121·0			[13]							19 01	
Arapuni .	121·95											
Wellington .	122·05											
Apia . .	124·2											
La Plata .	133·3			[15]					22 02		19 27	
Sucre . .	135·1			[23]				[—32]			19 38	
La Paz . .	136·55			[5]				[—13]	i 22 42	25 27	19 22	
Huancayo .	140·5			[31]							19 53	

6—*concld.*

Comp.	SKS	SKKS	PS	PPS	SS	SSS	G	L	M		Other phases and remarks.
	m. s.	m. s.	m. s	m. s.	m. s.	m. s.	m. s.	m.	s.		
				32 00				68·0			
			30 43	31 46	30 48			R60·0			SKP? 19m 50s±. Assumed —2m as time correction.
								q 52·0			
							50 19	61·8 LR 72·0m.			
	? 26 01							q 58·0			SKP 23m 04s.
								R 65·0			
	26 23	28 37	32 43					67·7	75·6		SKP 22m 59s.
					41 28	46 01		62·3			SKP 23m 13s; *i* 31m 29s; *e* 38m 01s, 30m 55s.

The Aftershocks of the Quetta Earthquake.

Within three days after the main shock, nearly twenty shocks were felt in the vicinity of Quetta. Of these, the one which occurred on June 2nd at 9h. 16m. 33s. G.M.T. was the most severe. In table 7 are given the times of arrival of the P and S waves from this shock at different observatories. The differences between the observed and calculated times of travel are also tabulated assuming the epicentre of the earthquake to have been the same as that of the Quetta earthquake and using Jeffreys-Bullen normal tables.

TABLE 7.—*Epc*: *29°·6 N., 66°·5 E.*; t_0 : 9^h 16^m 33^s.

Station.	Δ	P(obs).	P(O-C)	S(obs).	S(O-C)
	°	m. s.	Sec.	m. s.	Sec.
Agra . . .	10·45	2 19	—8	4 07	—17
Bombay . . .	12·1	2 53	3	5 08	3
Calcutta . . .	20·85	4 37	—2	8 32	8
Kodaikanal . .	21·9	4 54	4	8 59	15
Colombo . .	26·0	5 25	—4	10 10	12
Budapest . .	40·4	7 36	—1	13 18	—24
Zagreb . . .	42·3	7 51	0	14 17	6
Hongkong . .	43·2	7 57	—1	14 23	—1
Peichico . . .	44·5	8 10	1	14 44	1
Stuttgart . .	47·1	8 28	—1	15 21	1
Manila . . .	52·2	9 06	—2	16 29	—2
Batavia . . .	52·7	e 9 52	40	17 51	73
Kew . . .	51·15	i 9 14	—1	16 44	0
Amboina . .	67·7	e 10 00	—56	18 17	—96

Except for the large discrepancies between the observed and calculated values at Batavia and Amboina, the differences at the other stations are not sufficiently systematic to justify any change in the position of the epicentre.

In table 8 are given the phases of the main shock and aftershocks identifiable in the seismograms of the Agra Observatory.

TABLE 8.—*Phases of aftershocks from Agra seismograms.*

Date.	Times of phases in G.M.T.						Remarks.
	P	i-P	S-P	i-P	i-P	L-P	
	h. m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	
May 30	21 35 23	0 59	1 50				
"	23 36 22		1 49				
May 31	2 5 51		1 51	2 22		3 06	
"	i*8 26 25		1 55			3 10	Surface waves weak.
"	17 14 36		1 52	2 20		3 08	
June 1	4 32 36	0 57	1 48	2 18	2 54	3 07	
"	14 48 32		1 59				
June 2	*4 18 41		1 52				Surface waves weak.
"	e 9 18 50	0 58	1 48		2 56	3 10	

The S-P interval corresponding to 10°·45, the distance between Agra and the epicentre of the Quetta Earthquake is, according to Jeffreys-Bullen normal table 1^m 57^s and according to Jeffreys' continental surface focus tables 2^m 02^s.* In all the shocks listed in table 8, the measured intervals are smaller, the mean value being only 1^m 50^s. In at least four of the shocks recorded, however, there is a second S phase 8^s to 12^s after the first. If the second S is taken as the normal S, the first one would perhaps correspond to the "curtsey" often observed a few seconds before the normal S; but it should be mentioned that the first S in most of the cases now considered was very clear and began with an impetus.

Other fairly clear phases are observed at 0^m 59^s, 2^m 20^s, 2^m 55^s and 3^m 08^s after P. The third of these probably corresponds to Sg the transverse wave whose path lies wholly above the lower

* According to Macelwane's tables, the corresponding interval is 2^m 09^s and according to Gutenberg and Richter 2^m 02^s.

boundary of the granitic layer and the last to L the long wave. In the seismograms of the aftershocks recorded at Bombay, the times of incidence of the phases are difficult to determine with any precision, both P and S being generally emergent. Except that all the shocks occurred at nearly the same distance, no detailed information about travel-times can be obtained with their aid.

SUMMARY.

A Seismological study of the Baluchistan (Quetta) earthquake of May 31, 1935.

The times of arrival of the P waves from the Quetta Earthquake at different observatories throughout the world have been analysed and the position of the epicentre has been determined to be 29°·6 N., 66°·5 E, and the epicentral time to be $30^{d}\ 21^{h}\ 32^{m}\ 58^{s}{\cdot}5$ G.M.T. Among the prominent features of the seismograms were the gradual increase of amplitude interrupted by larger and larger impulses and the large amplitudes of the long waves compared with those of the preliminary, suggesting block movement and a shallow depth of focus. An analysis of the S-P residuals using Jeffreys and Bullen's normal tables showed that its mean value was about +3 sec. suggesting a depth of focus definitely less than the normal depth (10km.) and possibly also a complex process at origin. The energy of the earthquake is estimated to be about 10^{21} ergs. The phases of the aftershocks as noted in the Agra seismograms have also been tabulated.

SEISMOGRAMS OF THE BALUCHISTAN (QUETTA) EARTHQUAKE OF MAY 31, 1935.

PLATE 25, FIG. 1.—Bombay (Milne-Shaw), N.-S. Component.
FIG. 2 „ „ E.-W. Component.

PLATE 26.—Agra (Omori), N.-S. Component.

PLATE 27.—Calcutta (Omori).

PLATE 28.—Kew, N.-S., E.-W. and Z Components.

CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YUNNAN IN WESTERN CHINA. (10) THE DISTRIBUTION, AGE AND RELATIONSHIPS OF THE RED BEDS. BY J. COGGIN BROWN, O.B.E., D.Sc., M.I.M.M. (With Plates 29 & 30.)

CONTENTS.

I.—DISTRIBUTION AND GENERAL CHARACTERISTICS.

Introduction.

East of the Mekong, a great part of Central Yunnan is covered by a formation in which unfossiliferous red sandstones and shales predominate; extending over thousands of square miles and occupying a much larger

surface area than any other group of rocks, it has attracted the attention of every geologist who has visited the province, yet its age and relationship to similar strata in adjoining regions still remain matters of controversy.

Red formations generally attributed to one or more of the Mesozoic systems, or to some division of the Tertiary period, occur in many parts of South-Eastern Asia, but limiting our range to the territories close to Yunnan, they are found along the eastern shores of the Bay of Bengal, on the Mergui Coast; in the north-eastern parts of the Amherst district of Burma, through Northern Siam into the Federated Shan States and thence across Yunnan into Kueichow, Kwanghsi and Kwangtung. Again, from the Red Basin of Szechuan on the north, through Yunnan into the French provinces of Indo-China, they cover immense areas and stretch for unknown distances into Eastern Siam. (Pl. 29.) The unfossiliferous character of most of these sediments has led to widely divergent views of their ages and rendered their correlation an unusually difficult task. Yunnan may be regarded as the centre of the great region thus roughly indicated and any evidence which it can supply should help towards a solution of the problems which the Red Beds present further afield.

The Subsidiary Red Basin of Yunlung.

Crossing Yunnan from the direction of Burma by the Bhamo-Tali Fu-Yunnan Fu track, the Mekong gorge itself is excavated in the sub-metamorphic rocks of the Precambrian Kaoliang Series. These are at once overlain by red sandstones and shales outcropping with monotonous regularity for some 40 miles further to the north-east, to be followed either by the crystalline rocks of the steep western flanks of the T'sang Shan range near Tali Fu (25° 40′: 100° 10′), or by the old Palæozoic limestones of their lower slopes. (Pl. 30.) Northwards from the track similar strata extend in an unbroken sequence for at least 70 miles. I shall refer to this particular spread of Red Beds as the Yunlung Basin, from the town of the same name (25° 47′ : 99° 19′), the centre of one of the salt-producing regions of Yunnan, for this mineral is obtained in large quantities either as brine or as rock salt, from certain horizons of the formation. It is doubtful if the Yunlung Basin is a separate entity as some geologists have supposed; it is more probably a subsidiary prolongation towards the west of the main basin of Central Yunnan.

This central basin is best known from the exposures along the Tali Fu-Yunnan Fu (25° 3′ : 102° 40′) track on which they are practically continuous from the eastern edge of the Triassic Gulf of Yunnan-i, at Anningkuan (25° 23′ : 100° 51′) to Anning Chou (24° 56′ : 102° 29′), a distance of approximately 110 miles in a straight line. As it is along this route that most of the observations of recent years have been made and regarding which differences of opinion have arisen, the present account will be largely devoted to it. It would be misleading, however, to allow such centralization to obscure the fact that the Yunnanese Red Beds cover a far vaster surface than even this long section indicates. In the north of the province, across the Yangtze, I followed them from the river to the neighbourhood of Yungpei T'ing (26° 42′ : 100° 45′), a direct distance of over 30 miles, without finding their northern limit. In the far south, around Szemao (22° 48′ : 101° 3′), they are known to stretch to the Mekong at least, though again broken by a narrow zone of marine Triassic deposits; further south still their limits are again undemarcated though they probably cross from China into the Laos; moreover, I think that they occupy much of the course of the Papien Ho, or Black River, in Yunnan, from about the latitude of P'uerh Fu (23° 4′ : 101° 4′), to its head about latitude 24° 50′. Thence they cross its watershed into the upper valley of the Yüan Chiang, or Red River, a distance of over 180 miles as the crow flies from north to south; continuing further north they appear to wrap around the southern termination of the T'sang Shan* and so to join the subsidiary basin of Yunlung.

The Central Basin and Other Occurrences.

West of the karstic regions of Eastern Yunnan, in every direction traversed, both to the north and to the south of the Tali Fu-Yunnan Fu route, I met the Red Beds and there is little doubt that when the intervening areas come to be surveyed, they will be found to cover much of Central Yunnan, geologically unexplored up to the present time.

The Threefold Division of the Red Beds.

The Red Beds can be divided into three major divisions. The lowest consists of thick conglomerates containing pebbles of rolled quartz and limestone, followed by alternations of sandstones and shales of various bright tints. Thin laminæ of a marly nature are

* The T'sang Shan is the name of the high mountain ridge of Archæan rocks, rising to 14,000 feet, immediately to the west of Lake Erh Hai, on the shore of which Tali Fu is situated.

sometimes present. Good examples of this lowest group occur near Anning Chou, (24° 56′ : 102° 29′) in the Yunnan Fu neighbourhood[1] near Hungai, (25° 24′ : 100° 24′) at the head of the Mitu plain in Central Yunnan[2] and north of the Yangtze on the road to Mankuan (26° 20′ : 100° 24′), Yungpei T'ing district, where the conglomerates contain pebbles of jasper and red and green porphyrite[3]. Where the conglomerates are absent, the lowest subdivision is often distinguished by the vivid and rapidly changing colours of its weathered shaly bands; purple, reddish-purple and maroon, violet, red and pink, with layers of green, greenish-white and buff, through which thin ribs of speckled sandstone protrude. The prevailing tint of the soil is a bright Indian red[4].

The middle subdivision, of far greater areal extent than either of the other two, is predominantly shaly, usually of reddish and reddish-purple shades, often stained, spotted and flecked with green and sometimes of a distinct marly character. True calcareous horizons do occur but they are exceedingly rare and invariably thin. Of secondary importance in bulk are the sandstone bands, generally thin, red and soft, though occasionally more massive and harder, when paler tints and speckled varieties are often seen, as well as thin quartzitic layers, interbedded with reddish and reddish-violet clay shales. Associated with the thicker sandstone bands are the salt deposits which make the Red Beds of such economic importance. At Houching, in the Tingyuan Hsien district, the mineral occurs in patches and strings in a hard, red sandstone band of which about 20 feet are mined, but at most of the other localities, scattered in various parts of the province, weak brines, from which the salt is obtained by evaporation to dryness, are drawn from wells sunk into the saliferous horizons. Detailed accounts of a number of these occurrences and of the processes of manufacture are given in my account of the mines and mineral resources of Yunnan[5]. In Southern Yunnan there appears to be more variety in the sandstones of this middle subdivision than in the central part of the Province. Near Weiyuan T'ing, for instance[6] there occur soft, light red arkoses; hard, reddish-black sandstones with

[1] *Rec. Geol. Surv. Ind.*, XLIV, p. 114, (1914).
[2] *Rec. Geol. Surv. Ind.*, LIV, p. 74, (1923).
[3] *Rec. Geol. Surv. Ind.*, LIV, p. 325, (1923).
[4] *Rec. Geol. Surv. Ind.*, LIV, p. 309, (1923).
[5] *Mem. Geol. Surv. Ind.*, XLVII, pp. 156-180, (1923).
[6] *Rec. Geol. Surv. Ind.*, LIV, p. 311, (1923).

inclusions of dense red clay; hard, reddish marls showing dark, ochreous stains; banded light red and yellow sandstones; hard, white, quartzitic kinds and bluish-grey, fine-grained examples containing gritty bands of pea-sized quartz and felspar.

The third and uppermost division consists of rather soft, thick, red, fine-grained sandstones, passing sometimes into conglomerates, generally found on the crests of the ridges, always possessing quite low dips, in contrast with the generally high dipping and often contorted strata of the lower divisions, and in some cases lying practically horizontally disposed. This subdivision is only definitely known in and about the salt field of Central Yunnan and is particularly well exposed around Lufēng Hsien (25° 8′ : 102° 9′). Looking to the north-east from this city, a long escarpment crowned by these flat red sandstones stretches for a considerable distance, while in the open, tree-less valley to the south, good exposures exist. The red sandstones on the high ground between Hsiaoshihchiao (25° 14′ : 102° 8′) and Heiching (25° 22′ : 101° 47′) are perhaps of the same age, while the low dips of similar rocks some 50 miles further west, between Shachiao (25° 15′ : 101° 11′) and Tienshentang (25° 20′ : 101° 3′), may, in the absence of contrary evidence, justify their inclusion in the same subdivision.

Such, in brief, are the main rock types of the Red Beds, the age of which will now be considered.

II.—AGE.

A. Opinions of Earlier observers.

Ludwig von Loczy traversed the Yunlung Basin in 1880 but made few comments on this portion of his journey, remarking, however, that its sandstones, clay shales and occasional limestone conglomerates, with their very disturbed bedding and induced schistose cleavage, resembled the Mesozoic deposits of the provinces of Szechuan and Kwanghsi. On the section-traverse accompanying his notes the region is shown as occupied by Permo-Triassic rocks.[1]

Ludwig von Loczy, 1880.

[1] "Die wissenschaftlichen Ergebnisse der Reise des Grafen Bela Szechenyi in Ost Asien", Vol. 1, pp. 762-770, Vienna, 1892.

P. A. Duclos, 1895-97, and M. A. Leclère, 1897-99.

P. A. Duclos who travelled in China in 1895-97, directed attention to the red sandstones of the north-east of Yunnan and tentatively attributed a Permian or Triassic age to them.[1] M. A. Leclère, (1897-99) regarded the salt-bearing red rocks of Central Yunnan as Upper Permian and on his small map groups the Devonian, Carboniferous and Lower Permian together while indicating the Upper Permian and Trias under another colour.[2]

J. Deprat, 1909-11.

J. Deprat surveyed a large part of Eastern Yunnan in 1909-11, though the main group of Red Beds which he described are not continuous with those of Central Yunnan. They consist of conglomerates overlain by sandstones and variegated marls, followed by basalts and andesites and are placed at the top of the Thuringian in the Upper Permian. They occur in four elongated, disconnected but overlapping bands which commencing to the south-east of Linan Fu (23° 37′ : 102° 50′), stretch for some 120 miles in a north-north-easterly direction towards the Kueichow border beyond Luliang (25° 3′ : 103° 36′). The bands are narrow, usually attaining a maximum width of about five miles and tapering to the north and south, but the northern one rapidly broadens out beyond Lunan (24° 47′ : 103° 17′), so that at its extreme known limits near Lulaing, though broken by a narrow zone of Devonian rocks, it is nearly 25 miles across.

Amongst many interesting sections described by Deprat the following may be mentioned; near Tsin-chouei-tang, 14 miles north of Ami Chou (23° 40′ : 103° 16′), the conglomerates rest with high dips on the Middle Devonian and contain limestone pebbles with both Uralian and Permian fossils: at Wou-lou-si-chou, 17½ miles north-east of Linan Fu, the red sandstones are missing and the conglomerates, in this case resting on the Uralian and 210 metres (688 feet) thick, are followed by great thicknesses of basic rocks and tuffs: near Loukhi, approximately 14 miles north-west of Milê Hsien (24° 24′ : 103° 26′), the red sandstones are over 300 metres (984 feet) and the underlying conglomerates 150 metres (492 feet), thick.

Deprat stresses the episodic and inconstant character of the individual sandstone bands, their frequent marly and gypseous

[1] "La Mission Lyonnaise d'exploration commerciale en Chine", pp. 283-314, Lyons, 1898.

[2] *Annales des Mines*, Vol. XX, 9me Ser., pp. 287-492.

intercalations and the rapidity with which lithological changes take place in them laterally. The extraordinary variation in the ages of the underlying substrata, which may vary in a few miles between widely separated Permian and Uralian calcareous horizons, the thickness of which is fairly well known, leads him to insist on the enormous erosion following the epirogenic uplift which resulted in the formation of the conglomerates.

Deprat's survey touched the eastern edge of the Red Basin of Central Yunnan and its rocks are mapped, like the sandstones of the group just described, as "Série gypso-salifère, grèso-marneux". Between Yunnan Fu and Tungch'uan Fu (26° 24' : 103° 12'), where the basic lavas attain their greatest development, the Red Beds appear to be absent.

South of the latitude of Luliang, according to Deprat, above the Upper Permian Red Beds and the basic rocks, there follows a series of coarse sandstones and psammites which frequently contain coal seams. They are particularly well exposed in the Milê region and towards the north-east, where they exhibit an interrupted series of coal exposures over a distance of 80 kilometres (50 miles). At least 300 metres (984 feet) thick near Milê, they consist of dark, reddish-brown, well-bedded, somewhat incoherent, micaceous sandstones, passing into a complex of variegated marls, pulverulent marly shales and soft sandstones which in their turn grade insensibly into fossiliferous rocks of the Middle Trias. Both these divisions, here and elsewhere, lying either on the Lower Permian limestones or on the basalts, are placed in the Werfenian by Deprat. This is doubtless correct in the case of the uppermost of the two, as it contains typical forms of the Lower Trias of Europe amongst its lamellibranch remains. The flora of the coal seams of the lower division, however, contains *Gigantopteris nicotianæfolia* Schenk and although Zeiller believed the flora to be of Lower Triassic age, this particular plant, as I shall show later, is now generally accepted as an indication of the Middle Permian. The position assigned to the psammitic series by Deprat must therefore be revised.[1]

In my first account of the Red Beds as they occur in the Yunnan Fu area, published in 1914,[2] I described how their basal conglomerates rest on eroded foraminiferal limestones, which I believed to be of Uralian age. In the high

Personal Opinions.

[1] *Mem. Serv. géol. Indochine*, Vol. 1, Fasc. 1, pp. 153-174, (1912).
[2] *Rec. Geol. Surv. Ind.*, Vol. XLIV, Pt. II, p. 114, (1914).

cliffs of the western shore of the Yunnan Fu lake, Deprat had at that time mapped limestones which he considered to belong to the Lower and Middle Permian and I came to the conclusion therefore, that the Red Beds of the same neighbourhood could not be older than Upper Permian. Later, more extended studies led me to believe that the Red Beds must extend into the Trias, a view expressed cautiously in 1916 and definitely adopted in 1923.[1] [2]

F. R. Cowper Reed, 1927.

The publication of Dr. F. R. Cowper Reed's results of his examination of my fossil collections from Yunnan, in 1927, though it could supply no direct evidence on the age of an unfossiliferous formation, at the same time brought forward no new facts to lead to a revision of the limits I had already allotted to the Red Beds.[3] The underlying limestones were classified into Lower Carboniferous, Upper Carboniferous and Permo-Carboniferous, and, amongst the foraminifera, the only species specifically determined was *Neoschwagerina craticulifera* (Schwager), from Tzumenlu in the vicinity of Yunnan Fu. Once classified as an Upper Uralian form and indeed placed by Cowper Reed in the Upper Carboniferous, this species is now generally regarded as belonging to the Lower Permian.[4]

At Talishao (25° 14′ : 99° 20′), some 20 miles to the west of the western edge of the Red Basin of Yunlung, from which it is separated by a band of pre-palaeozoic rocks and brecciated limestone of supposed Devonian age, I made a large collection of fossils, regarding which Dr. Cowper Reed has remarked :—" The relations of this fauna point clearly to some part of the Permian described by previous authors in Eastern Asia. Many of the species are identical with or closely allied to those occurring in the Middle and Upper Productus Limestones ".[5] Loczy had already described a few fossils from the same locality as Permo-Carboniferous, but Frech correlated the beds with the Arta Stage of the Urals which he regarded as the equivalent of the Lower Productus Limestone of the Salt Range.[6]

Grabau has enumerated Cowper Reed's provisional list of these fossils which was published in 1924,[7] and remarks as follows :—

[1] *Rec. Geol. Surv. Ind.*, Vol. XLVII, Pt. IV, p. 229, (1916).
[2] *Rec. Geol. Surv. Ind.*, Vol. LIV, Pt. III, p. 318, (1923).
[3] *Pal. Ind.*, Vol. X, Mem. No. 1, (1927).
[4] *Bull. Serv. géol. Indo-Chine*, Vol. XIX, Fasc. 2, p. 18, (1931).
[5] *Pal. Ind.*, Vol. X, Mem. No. 1, p. 108, (1927).
[6] *Ibid.*, p. 105.
[7] *Rec. Geol. Surv. Ind.*, Vol. LV, Pt. 4, pp. 314-326, (1924).

"Reed, following Tschernyschew, refers this fauna to the Permo-Carboniferous, considering it essentially equivalent to the Middle Productus Limestone. According to the classification here adopted, this is regarded as Middle Permian and this is in accordance with the faunas of China and Mongolia. The succeeding Permian horizons are represented by continental Red Beds".[1] Whatever the exact position of the Talishao beds may be in the Chinese Permian, the Red Beds must be much younger on account of the pronounced unconformity at their base.

The bearing of Dr. Cowper Reed's investigations of my Mesozoic collections from Yunnan and of the more recent determinations of Sir A. Seward and Prof. B. Sahni of the plant remains, on the upper limit of the Red Beds, is deferred to a later paragraph.

B. Opinions of Later Observers.

J. W. and C. J. Gregory, 1925.

My views on the age of the Red Beds were confirmed by Prof. J. W. Gregory, at any rate as far as the Yunlung Basin is concerned, in his account of the Percy Sladen Expedition to Chinese Tibet in 1922.[2] Under the heading "Permo-Triassic Systems", he states that the Carboniferous was succeeded in North-Western Yunnan by a widespread series of red rocks which are economically important for their salt beds and which occupy three basins. The first and largest, extending over about 1,500 square miles, reaches from near Lanping (26° 27′ : 99° 30′ approx.) on the north-west, past Shihmenching and Yunlung, across the Yungchang-Tali Fu road in the south, and from near the Yungping river on the west (25° 27′ : 99° 31′) to Yangpi (25° 40′ : 99° 59′) on the east. A second basin lies farther east near Yunnan Fu, whilst the third occurs at Yakolo on the Mekong, (29° 4′ : 98° 33′) south-west of Batang in Szechuanese Tibet. Prof. Gregory did not travel further east than Tali Fu and he was thus unaware of the far greater extent of the Red Beds in Central Yunnan than in the Yunlung Basin, which I have already suggested may only be a projecting portion of the former.

Gregory described the rocks as chiefly red shales and sandstones, some of aqueous and some of subaerial origin. He found no traces

[1] "Stratigraphy of China", Vol. 1, p. 490, (1923).
[2] *Phil. Trans.*, Ser. B, Vol. 213, p. 224, (1925).

of marine beds in the series, but considered that the proximity of the sea during the deposition of part of them was indicated by the thick beds of rock salt and gypsum. The rocks, as a whole, recalled to his mind those of the British Trias, one of the most widely used freestones in particular, which is cut into slabs and arches for graves, being indistinguishable from the St. Bees Sandstone of the English Bunter. Some of the red marls are also similar to those of the Keuper.

"The age of this series is fixed", he states, "in the absence of fossils, by its stratigraphical relations. It rests against the Carboniferous along its northern margin between Lanping and Yangtsen, and clearly overlies the fossiliferous Carboniferous limestone near Shuichai, and, according to Desgodins and von Loczy, also near Yakalo.[1] Mr. Coggin Brown refers these beds to the Upper Permian and Lower Trias, and that age seems most probable.[2] Their deposition earlier than the marine Trias of north-western Yunnan agrees with their physical history; for the marine limestones of Likiang (26° 58′ : 100° 13′) and the Janu La* (about 28° 20′ : 99° 2′) and the salt-bearing red beds of Yakalo and the Yunlung basin indicate such different geographical conditions that these two series of rocks were probably formed at different times".

The marine Trias referred to above was determined by Prof. Gregory himself and by Dr. Cowper Reed to belong to the upper part of the system, but in the absence of contacts of the two groups, the upper limits of the Red Beds in the Yunlung Basin remain conjectural.

The coarse conglomerate followed by red and green sandstones and grits and by chocolate coloured shales which cover the crystalline rocks of the T'sang Shan to the east of the basin, near Yangpi, which Gregory regarded as forming part of his Minchia Series of Devonian age, probably belong, in my opinion, to the Red Beds, but, in any case, as he was well aware, a little further to the south, the Permo-Trias must rest directly on the pre-Palæozoic floor. Similar conditions apply in the Mekong valley at its western limits, but here the basal conglomerates have not been found and the contact may be abnormal.

[1] "Die Wissenschaftlichen Ergebnisse der Reise des Grafen Bela Szechenyi in Ostasien", Vol. 1, p. 723, (1893).

[2] *Mem. Geol. Surv. Ind.*, Vol. XLVII, p. 58, (1923).

* The Janu La (15,800) is the pass, south-east of Atuntzu, over the Mekong-Yangtze dividing range.

Japanese Geological Map of Yunnan.

On Sheet No. 14 of the Geological Atlas of Eastern Asia, on the scale of 1 : 2,000,000, published by the Geographical Society of Tokyo in 1929, the Red Beds of the centre, west and south of the Province are grouped together as Permo-Triassic shales and sandstones, stretching from the Yangtze valley, north-north-east of Tali Fu, far to the south. The Red Beds of Eastern Yunnan are classified as Permo-Carboniferous shales and sandstones. Those of the Red Basin of Szechuan, the southern portion of which enters this sheet, are shown as shales and sandstones of Upper and Lower Cretaceous ages, respectively. No connection is indicated as existing between the two basins which are separated by older rocks to the north and north-east of Yunnan Fu.

Views of Arnold Heim and K. Krejci-Graf. (1930).

The Permo-Triassic age of the Yunnanese Red Beds was challenged by Arnold Heim and K. Krejci-Graf in 1930. They travelled from Yunnan Fu through Fumin Hsien and thence across the Yangtze into Szechuan by the Huili Chou route, remarking that with the exception of the valley of this river, they traversed Red Beds continuously for ten days. The Red Beds are stated to be unfossiliferous and as thick and typical as those of the Red Basin of Szechuan between Chungking and Chengtu. An older, folded, basal series containing some green sandstones, is followed by blood red shales, marls and sandstones, from 2,000 to 3,000 metres (6,560—9,840 feet) thick, and over these again lay brick red sandstones at least 500 metres (1,640 feet) in thickness, forming the cores of the troughs. These three groups are compared with the three subdivisions of the younger Red Beds of Szechuan as described by Heim, the oldest of which, the Tseliutsin (Tzuliutsing), or Ts'ienfuyen formation, as it is now officially termed by the Geological Survey of China, carries a fresh water, molluscan fauna of Wealden type, and on grounds of lithological analogy the Red Beds of Yunnan were also regarded by Heim and Krejci-Graf as Cretaceous. It is added that in the same way as von Richthofen spoke of the "Red Basin of Szechuan", so it is possible to speak of a "Red Basin of Yunnan".[1]

Prof. Arnold Heim however has abandoned his opinion on the

[1] *Zeit. Ges. für Erdkunde zu Berlin*, pp. 266-69, (1930).
Geol. Surv. Kwangtung & Kwangsi, Spec. Pub., No. VI, (1930).
Bull. Geol. Soc. China, Vol. IX, No. 1, (1930).
Geol. Surv. Kwangtung & Kwangsi, Spec. Pub., No. XIII, p. 24, (1932).

Cretaceous age of the Red Beds between Yunnan Fu and the Yangtze. In private communications (1936) he has informed me that although these formations are almost indistinguishable from the Cretaceous Red Beds of Szechuan, he has now come to the conclusion that those in the neighbourhood of the Yunnan Lake are probably Permo-Triassic or Triassic, because they directly overlie igneous horizons correlated with the Omeishan Basalt. As for the remainder farther to the north, he believes they are probably Devonian to Carboniferous for they occur below the Permian (?) limestones, and, further, because the late V. K. Ting discovered fossils of Devonian to Carboniferous ages in the Red Beds of Northern Yunnan and their extensions in Southern Szechuan. This find was announced in a private letter by Dr. Ting to Prof. Arnold Heim.[1] My remarks on this problem are given in a later paragraph.

K. Krejci-Graf's Second Classification. (1931).

In a later paper Dr. Krejci-Graf altered the classification originally adopted by Prof. Heim and himself and divided the Red Beds of both Yunnan and Szechuan into an Upper and a Lower Group.[2] The Upper Group is stated to be found in precisely the same development from Yunnan Fu to Fulin in Yunnan and thence to Chungking on the Yangtze in Szechuan. It often forms the innermost parts of the troughs and consists of a brick red sandstone complex as a middle subdivision, above and below which are red marls, clays and sandstones. The uppermost division does not occur everywhere. The lowermost of the three is stated to contain basaltic flows and probably tuffs, in addition to thin coal seams and the various occurrences of salt and gypsum which are exploited locally. It is thought that these Upper Red Beds are of Tertiary age but no definite proof is said to exist. The main portion of the Red Beds of the localities named above, consists of the Lower Marl Group of the Upper Red Beds and Krejci-Graf appears to think that the salt deposits are probably of Tertiary age.

The Lower Red Beds are red and yellow marls, shales, sands and conglomerates with white and reddish, impure limestones in the northern region (Szechuan). Of local and irregular development, they are found between Yunnan Fu and Sitsang (Ningyuan Fu), in the area between Yatshou Fu and Tshingkouho and again to the east of this line, but the occurrences are erratic, so

[1] *Ibid*, p. 23, footnote, (1932).
[2] *Centralblatt für Min. Geol. & Pal.*, Abt. B, No. 8, pp. 414-415, (1931).

that although present on one flank of a syncline, they may be absent on the other, or, failing entirely in one trough, they may be seen again in the next. No angular discordance was observed between the Upper and Lower Red Beds and the age of the latter is indicated as Cretaceous, on the strength of the *Naiadidæ* which have been found in it. Dr. Arnold Heim is quoted as the authority for this opinion,' but, as pointed out above, he no longer holds this view as far as the Red Beds of Yünnan are concerned.

The text of a still later paper by Krejci-Graf on the country between Yunnan Fu and the Yangtze, deals almost exclusively with morphological problems. It contains, however, a stratigraphical table in which the Red Beds are classified as follows :—

Formation and Age.	Stages and Thickness.	Deposits.	
	Upper Clay Series over 500 metres. (1,640 feet).	Red Clays to Sandstones.	
UPPER RED BEDS .	Brick Red Sandstone, 200-400 m. (?) (650—1,300 feet).	Brick Red Sandstone .	Ripple Marks.
		—?—?—?—?—	
Tertiary to Cretaceous.	Lower Clay Series about 2,000 m. (6,500 feet).	Red Clays to Sandstones. Some layers of Basalt and Tuff. Rare and local thin coal seams or carbonaceous shale.	Cross Bedding. Gypsum. Salt.
LOWER RED BEDS. Cretaceous.	400-500 m. (1,300-1,640 feet).	Red and yellow Clays to Sandstones and Conglomerate. Cross Bedding, Ripple Marks, "Hieroglyphen."	

The Upper Clay Series was only observed in a neighbouring region, presumably Szechuan. The broken lines in the table indicate discordances. Below the Red Beds lie 500 metres (1,640 feet) of Permo-Triassic melaphyre, followed discordantly by 1,100 metres (3,600 feet) of Permo-Carboniferous limestones. Elsewhere, 500 metres of Rhætic-Liassic coal measures intervene between the Red Beds and the igneous rocks.

On the geological section accompanying this paper the Red Beds are shown in two groups, one of which includes the Brick Red Sandstones, and the other all the strata below them. The latter group

occupies 96 *per cent.* of the total distance between Ma Ti and the Yangtze (some 48 miles), while the former only occurs in three small, synclinal outliers of limited extent. Further, at the Yangtze itself and again near Ma Ti, the section displays Permo-Carboniferous limestones overthrusted on to Red Beds. This is another point with which Dr. Arnold Heim informs me he does not agree[1].

Another account of the expedition during which these observations were made has been published in English but is unobtainable in London. In a private letter, however, Dr. Krejci-Graf states that it adds little to the information given in the papers summarised above[2].

W. Credner's Observations.

W. Credner, who crossed both the Central and Western (Yunlung) Basins, also divided the Red Beds of the former into an Upper and a Lower Group, separated by a very pronounced unconformity. He gives a figure of the critical section near Lufêng Hsien showing a strongly folded, red sandstone-shale formation overlaid discordantly by red sandstones, in which the angle of dip gradually flattens out until horizontality is attained in the uppermost part.

A comparison with conditions in French Indo-China and Siam, both of which he knew, led Credner to attribute the Lower Group, which is probably thousands of metres thick, to the younger Mesozoic, while the upper, undisturbed Group "probably has to be placed into the Middle and Upper Tertiary". On his traverse map, the Upper Red Beds are confined to a small area in the neighbourhood of Lufêng Hsien[3].

The Work of Edmond Saurin. 1933.

The French geologist, E. Saurin, has investigated the country between Yunnan Fu and Yuanyungching, a town in the salt-bearing region of Central Yunnan, referred to in my own reports as Houching, and shown as such on Sheet 31 N. W., (1 inch=4 miles), North-Eastern Frontier Surveys, 1899-1900, lying about 25 miles to the east of Tingyuan Hsien (25° 20′ : 101° 34′). It is one of the more important salt-producing towns of this part of Yunnan, and, in addition, one of the few where rock salt is mined. From Yuanyungching,

[1] *Geol. Rund.*, Bd. XXV, Heft 5, pp. 305-312, (1934).
[2] *Sci. Journ., Sun Yatsen Univ., Canton,* (1931).
[3] *Mitt. aus dem Geog. Inst. der Sun Yatsen Univ. Kanton.* Band 1, Nos. 1 and 2, 1931. An English translation of No. 2 is available.

M. Saurin made his way south through Aluching to the track which leads from Kuangtung Hsien (25° 10′: 101° 44′) to Yunnan Fu, and was thus enabled to examine completely a limited portion of this region. Restricted though this area may be, the results it has yielded stand in striking contrast with those of the earlier and more hurried traverses[1].

M. Saurin divides the Red Beds into three subdivisions as follows :—

(1) A basal conglomerate, resting on a variable substratum, followed by rapid and versicoloured alternations of sandstones (sometimes calcareous), and of shaly or marly clays.

(2) Shaly clays, marls and soft, dark claret-coloured sandstones, with rare and thin intercalations of limestone and of violet, arkositic sandstones, spotted with green tints. In this group the shales greatly predominate, and it is also the salt and gypsum-bearing horizon, the former mineral occurring sometimes in the form of weak impregnations, or more rarely in the form of rock salt. At a locality near Anning Chou, there occurs in this subdivision the only fossiliferous horizon yet reported from the Red Beds of Yunnan. It has yielded *Estheria* sp. and *Estheria Zeili* Mansuy, which are found with indeterminable plant remains in sandy purple shales of the common type. Although phyllopods are of little assistance in precise stratigraphical determinations, it is interesting to recall that Mansuy compared *E. Zeili* with *E. mangliensis* Rupert Jones, of the Mangli Beds of India, which are now correlated with the Lower Trias[2]. Mansuy's species was originally described from the red shales of the "Terrain Rouge" of Muong On Tai in the Haut Laos.

(3) Compact, fine-grained red sandstones, locally passing into conglomerates, only found to the west of Anning Chou. The total thickness of the Red Beds in the salt-producing region is estimated at from 2,000 to 3,000 feet.

[1] *Bull. Soc. géol. France* ; 3, 5^{me} Série, pp. 441-473, (1933).
[2] *Mem. Geol. Surv. Ind.*, Vol. LVIII, p. 157, (1931).

M. Saurin also refers to the occurrence of Rhætic coal measures at Y Pin Lan (Y'u-pi-lang of Sheet No. 31, North-Eastern Frontier Surveys), a village some two miles south of the Lufêng Hsien-Kuang-tung Hsien track and about 11 miles in a straight line west of the former town. At this place, a coal seam, 6 to 9 feet thick occurs, underlain by grey and yellowish-brown clay-shales, friable red sandstones, sandy dark green shales and greenish-yellow arkoses and while the dip of the latter is high to the east, it gradually becomes subhorizontal in the felspathic sandstones. Above the coal seam follows a coarse, white, quartzose sandstone with carbonaceous debris, recalling some occurrences of the "grès supérieurs" of the Laos and of Cambodia. From the shales enclosing the coal seam the following plant remains were collected:—*Podozamites distans* Presl., *Clathropteris platyphylla* Gœpp. and *Tæniopteris* cf. *Leclèrei* Zeiller. These fossils are believed to indicate the Rhætic age of the flora and its analogy with the similar one found in association with coal seams in other parts of Yunnan and Szechuan[1]. It is stated that the coal measures are moulded on an anticlinal arch of Red Beds, that there is no appearance of discordance between the upper part with coal and the underlying psammitic sandstones, but that a progressive slowing down of the folding is in evidence here as it is in the Red Beds themselves elsewhere.

It is suggested by Saurin that the upper part of the Red Beds which occurs in full development a short distance further north passes laterally into the psammitic sandstones, carbonaceous shales and coarse, white sandstones of the coal measures and that the latter would thus be the stratigraphical equivalents of the compact, soft red sandstones which terminate the Red Beds about Lufêng Hsien. The coal measures are believed to represent the deposits of an ancient contemporary depression, doubtless lagunar at first and then becoming lacustrine; the products of erosion and the results of slow, orogenic movements. It follows that the Red Beds, the upper part of which passes into a Rhætic, or as some palæobotanists would probably consider, a Norian horizon, dated by its flora, must be older than this.

[1] *Mem. Geol. Surv. Ind.*, Vol. XLVII, Pt. 1, pp. 66-69, (1923).
Rec. Geol. Surv. Ind., Vol. LIV, Pt. 1, pp. 78-82, (1923).
Ibid., pp. 330-332.

C. The Alleged Existence of Devonian Red Beds in South-Western Szechuan and North-Central Yunnan.

Continental Devonian of Huili.

In his Presidential Address to the Geological Society of China in 1929, the late Dr. V. K. Ting announced that the valley of Huili Chou, lying between the high mountain ranges of the Lungtsaoshan and Taliangshan, on the west and east, respectively, in the extreme south-west of Szechuan, consists largely of red sandstones of Devonian age. He added, "Middle Devonian fossils have been found by me in the region south of the river in precisely the same formation. A fragment of *Leperditia* found in the district itself assures me that the correlation is correct".[1]

I have crossed the Lungtsaoshan and can confirm Ting's observation that it is built of rocks of Permian age and it is quite possible that in the Huili valley, there is another example of the protrusion of the older Palæozoic floor through younger rocks.

Middle Devonian of Chingchiangkai.

That Devonian rocks do occur elsewhere in this manner is certain. On the Tali Fu-Yungpei T'ing route, after traversing a great thickness of Permian volcanic rocks and crossing the Yangtze at the Chingchiangkai ferry, fossiliferous limestones occur from which I obtained a large collection of Middle Devonian corals, brachiopods and cephalopods. The limestones are followed by overlying Red Beds, the junction being marked by a conglomerate in which jasper and porphyrite pebbles are the commoner rocks; taking these to be derived from the Perrmian igneous suite, I regarded the Red Beds themselves as late Permian or early Mesozoic.[2]

Continental Lower Devonian of Eastern Yunnan.

The continental Lower Devonian of Huili Chou has its counterpart in Eastern Yunnan where the upper part of the Silurian consist of sandstones with *Modiolopsis*, *Lingula*, *Leperditia* and fish remains.[3] These beds show a progressive increase in fresh water conditions which culminated later in the continental deposits of the Lower Devonian from which *Arthrostigma gracile* Daws., and

[1] *Bull. Geol. Soc. China*, Vol. VIII, No. 2, pp. 160-161, (1929).
[2] *Rec. Geol. Surv. Ind.*, Vol. LIV, Pt. 3, p. 325, (1923). *Pal. Ind.*, N. S., Vol. X, Mem. No. 1, pp. 6-19, (1927).
[3] *Bull. Geol. Soc. China*, Vol. XV, No. 1, p. 35, (1936).
Bull. Geol. Soc. China, Vol. XVI, pp. 7-8, (1937).

other plants have been described.[1] These lower Devonian rocks are confined to quite restricted areas about Chü-ching Fu (Lat. 25° 32′ : Long. 103° 47′) and another city, Chanyi Chou, some 10 miles further north in the extreme east of Yunnan.

Prof. J. W. Gregory's Minchia Series of Devonian Age.

In North-Western Yunnan, reaching from north of Tali Fu (Lat. 25° 40′ : Long. 100° 10′) to Likiang Fu (Lat. 26° 53′ : Long. 100° 14′); from Chitsung (Lat. 27° 35′ : Long. 99° 34′) to Atuntzu (Lat. 28° 30′ : Long. 98° 53′), and again, in the Mekong valley itself, north of Weihsi T'ing (Lat. 27° 11′ : Long. 99° 16′), there occurs a series of purple, red and green sandstones, grits and shales, often associated with porphyries, basalts, diabases, tuffs, agglomerates and flows of dolerite, spilite and rhyolite, which Prof. Gregory termed the Minchia Series and which he believed to be of Upper Devonian age. I do not accept this classification in its entirety for the southern limits to which these rocks extend, the only ones with which I am acquainted, but the occurrence of *Uncinulus procuboides* Kayser var., in the neighbourhood of the Janu La, is regarded by Dr. Cowper Reed as proving the presence of Upper Devonian rocks there. In any case there appears to be nothing in common between the Minchia Series of Gregory and the continental Lower Devonian of Eastern Yunnan or of the Huili valley in Szechuan.[2]

V. K. Ting on the Triassic and Permian Age of the Red Beds of Central Yunnan.

Unfortunately Ting did not specify the locality of "the region south of the river", from which he obtained this particular Middle Devonian fauna, but as he was personally responsible for the rich collections of the Geological Survey of China from the Middle Devonian of Eastern Yunnan, in all probability this was the region he had in mind. The matter is not likely to be settled until the proposed posthumous publication of his field notes takes place, a tribute to the memory of a great Chinese geologist which will undoubtedly lighten many obscure stratigraphical problems.

At the same time, it is possible to prove that those geologists who read into Ting's remarks a presumption that the Middle Devonian fauna in question came from the Yangtze-Yunnan Fu area, and conclude therefrom that the Red Beds which cover almost the

[1] *Pal. Sinica*, Ser. A, Vol. 1, Fasc. 2, [1927].
Pal. Sinica, Ser. A, Vol. 1, Fasc. 4, [1936].
[2] *Phil. Trans.* Ser. B, Vol. 213, pp. 220-222, 287-289, [1925].

whole of it, are of Devonian age, are interpreting them in a way which he never intended.

There can be no doubt that for some years Ting regarded the greater part of the Red Beds of Central Yunnan as of Triassic age, and further, that he impressed this view on his colleagues. For example, T. K. Huang has stated:—"In Central Yunnan the Liupakou Series [of the Permian] is wanting, the Triassic Red Beds coming directly upon the basaltic lava, according to V. K. Ting."[1]

He also rejected the theory that any of the Red Beds of Yunnan are contemporaneous with the red, continental Cretaceous formations of Szechuan, or with the red Tertiary deposits of certain other provinces. In this case it is fortunate that his own words can be quoted. After referring to the fact that most writers on Szechuan fail to recognise any unconformity between the Jurassic coal measures and the overlying sandstones, he continues as follows:— "In Yunnan the difficulties are greater because no sedimentary rocks younger than the Trias have been met with, except those of the Pliocene, the characteristic Red Beds [*i.e.*, those of Szechuan] being absent.[2]

A few years later Ting adopted the view, in conjunction with Prof. A. W. Grabau, that the Red Beds in question are of Upper Permian age, a standpoint which he maintained at the Sixteenth Session of the International Geological Congress in Washington in 1933 (see p. 538).

D. Further considerations on the Age of the Red Beds.

The Horizon of the Underlying Permian Limestone.

Neoschwagerina craticulifera (Schwager) reported by Dr. Cowper Reed in my own collections from Tzumenlu, near Yunnan Fu[3] was found again by Saurin at Tiefongngan, north of the city, where it occurs in limestone resting on basaltic tuffs and where it is also associated with *Fusulina brevicula* Schwager and *F. japonica* Gumb. All these species are characteristic of the Lower Permian and in Indo-China their horizon follows directly above the transition beds between the Uralian and the Permian. But M. Saurin has also stated that *Neoschwagerina Douvillei* Ozawa occurs in the limestone cliffs above the pagoda of Heyaszeu, to the west of Yunnan Fu, and this is a

[1] *Mem. Geol. Surv. China*, Ser. A, No. 10, p. 64, [1932].
[2] *Bull. Geol. Soc. China*, Vol. VIII, No. 2, p. 169, [1929].
[3] Page 521.

form which is characteristic of the terminal horizons of the Permian in both Indo-China and Japan.[1]

If *N. Douvillei* really is a well founded zone fossil as thus indicated, the possibility of any part of the Red Beds above its horizon belonging to the Permian is precluded, because in many places the underlying limestones were deeply eroded, in others reduced to a peneplain and perhaps in extreme cases entirely removed, before the deposition of the Red Beds themselves commenced. In M. Saurin's opinion these events imply an emersion in Lower Triassic and perhaps in Middle Triassic times and he concludes that the folded Red Beds belong either to the Middle and Upper or only to the Upper Trias as far as the Carnian, while the horizontal red sandstones are of Norian-Rhætic age.[2]

The question arises, however, to what extent are the elaborate zoning schemes, adopted for the subdivision of the Anthracolithic of these parts of Asia and based on the vertical distribution of the Fusulinidæ, reliable. Evidence, in fact, is accumulating that the stratigraphic value of a particular species as a zone index fossil is to be regarded with suspicion. In the case of Indo-China, J. Gubler has demonstrated survivals across several so-called zones.[3] He admits only two horizons in the Indo-Chinese Permian, characterised by *Neoschwagerina craticulifera* and *N. multiseptata*, respectively, and regards more detailed zoning and synchronisation as hazardous if not fantastic.[4] From the Productus Limetone of the Hindu Kush, R. Furon has reported the co-existence of the supposed typical Lower and Upper Permian forms, *N. craticulifera* and *Sumatrina annæ*[5]. From the Lower Permian Maokou Limestone of Kwangsi, C. Li and W. Y. Chang obtained not only *N. craticulifera*, but, amongst other forms *N. Douvillei*, the identical species which Saurin believes proves the Upper Permian age of the Yunnan Fu rocks.[6] T. K. Huang has stated that all the species of fusulinids quoted by himself as occurring in the Maokou fauna are assembled in a single horizon and cannot be adapted into any smaller subdivisions.[7] Forms are thus included in the Lower Permian in this instance, which have

[1] *Op. cit.*, p. 449.
[2] *Ibid.*, p. 461.
[3] *Bull. Soc. géol. France*, Vol. IV, 5th Ser., p. 443, [1934-35].
[4] *Mem. Soc. géol. France*, Vol. XI, Fasc. 4, No. 26, p. 149, 156, [1935].
[5] *Bull. Soc. géol. France*, Vol. 4, 5th Ser., p. 70, [1934-35].
[6] *Bull. Geol. Soc. China*, Vol. XV, p. 275, [1936].
[7] *Bull. Soc. géol. France*, Vol. 4, 5th Ser., p. 446, [1934-35].
Mem. Geol. Surv. China, Ser. A, No. 10, p. 37, [1932].

been zoned individually from the top to the bottom of the whole system by other writers. Indeed, if we accept the views of the Geological Survey of China, limestones bearing this *Neoschwagerina craticulifera* fauna, extensively developed in Eastern Yunnan and elsewhere, must be classified with the Maokou Limestone of South-Western Kueichow, and placed at the top of the Yangsinian, the lower of the two great divisions into which the Permian of Southern China is divided. Thus the occurrence of *Neoschwagerina Douvillei* in the limestones near Yunnan Fu would not appear to invalidate their Lower Permian age.

The Red Beds and the Lopingian.

Above the Yangsinian follows the Lopingian and in searching for evidence which may have a bearing on the problem of the lower limit of the Red Beds, its development in Eastern Yunnan, North-Western Kueichow and the extreme south-west of Szechuan is worthy of brief attention. In these regions, according to T. K. Huang[1] it is represented by the Liupakou Series of continental shales and sandstones with a thickness usually below 200 metres (650 feet). It invariably contains thin coal seams and carries the *Gigantopteris* flora. It generally rests on basaltic lava flows which in their turn overlie the Maokou Limestone with its *Neoschwagerina craticulifera* fauna, and which we have already seen underlies typical Red Beds in the Yunnan Fu neighbourhood. Following the coal-bearing horizons there occurs a thick succession of red shales and sandstones, often lithologically inseparable from the Liupakou beds themselves, and from horizons about the middle of these Triassic pelecypods have been obtained in Kueichow.

This generalised section of Huang's agrees with that given by Deprat for Eastern Yunnan, except that the latter placed his "Grès grossiers et psammites rouge-brune à niveau de charbon à *Megalopteris nicotianæfolia*" in the lowest Trias, and with the further exception, that between the basalts and the underlying Lower Permian limestones there intervenes his thick series of sandstones, variegated marls and conglomerates.

In Central Yunnan, however, west of the longitude of Yunnan Fu, as no trace of the Liupakou Series or of its associated coal seams and flora has been found either by myself or by any other geologist, it must be regarded as missing, unless the basic rocks or some part

[1] *Mem. Geol. Surv. China*, Ser. A, No. 10, p. 64, [1932].

of the Red Beds themselves are its equivalents. The thickness of these basic rocks is very variable and attains its maximum in the Yangtze valley of Yunnan. While the Red Beds rest upon them in some localities, in others they were completely removed or were never present before their deposition. Huang, after noting that in the centre and west of Yunnan, the basic rocks are followed by Triassic Red Beds, suggests that the Liupakou Series " was actually replaced by basaltic lavas ".[1] V. K. Ting, however, recorded *Lyttonia,* a common genus of the Lopingian, from below the lavas of the western part of the Tungchuan district of north-eastern Yunnan and, at first sight, it would appear, therefore, that these basic rocks are younger than the Liupakou Series, which hereabouts is largely absent. As the Lopingian is of Upper Permian age, according to Huang, the probability would then be, granting the existence of similar conditions over Central Yunnan, that the Red Beds are entirely confined within the limits of the Trias. This conclusion should not be lightly accepted for it assumes that the basic rocks in question are the equivalent of the Omeishan Basalt, and while this may be correct, there are, as I have pointed out in the last paper of this series, eruptive rocks in Yunnan both older and younger than the Omeishan Basalt.[2] Even as regards the latter itself, H. C. T'an has recently stated :—" The time of the vulcanism is not strictly determined and it may be of Middle Permian age."[3] Again, *Lyttonia* though uncommon outside the Choutang Series has been recorded from below the Lopingian. Finally, as is shown in the next paragraph, the Upper Permian age of the Lopingian is not accepted by all authorities.

The Age of the Gigantopteris Flora and its bearing on the Red Beds.

The coal-bearing, *Gigantopteris* Beds of Eastern Yunnan (the Liupakou Series), are succeeded as already mentioned, by thick, red, unfossiliferous sandstones and shales, often impossible to distinguish from the true Liupakou Beds themselves. This lithological resemblance naturally suggests a brief examination of the accepted position of the Chinese *Gigantopteris* flora in the geological scale. Palæobotanists including T. G. Halle, D. White, W. Gothan and H. C. Sze, as quoted by the last named,

[1] *Mem. Geol. Surv. China,* Ser. A, No. 10, p. 70, [1932].
[2] *Rec. Geol. Surv. Ind.,* Vol. 71, Pt. 2, p. 174, [1936].
[3] *Bull. Geol. Soc. China,* Vol. XVI, p. 396, [1936-37].

regard it as of Lower Permian age.[1] T. K. Huang, however, places it in the Upper Permian on faunal and stratigraphical grounds, stating :—" The *Gigantopteris* Beds are simply the land facies equivalent of the Choutang Series which carries *Lyttonia richthofeni* "[2] and, again, " The age of the *Gigantopteris* flora is undoubtedly Permian. It is contemporaneous with the *Lyttonia richthofeni* fauna (Choutang fauna) and slightly older than the *Oldhamia decipiens* fauna (Changhsing fauna). Its exact age, therefore, depends upon the age of these faunas. Noetling considered them Upper Permian, while Frech and Grabau took them as Middle Permian. Since the *Oldhamia* fauna is the latest known Permian brachiopod fauna in China, the writer is rather inclined to follow Noetling's ideas."[3]

I am greatly indebted to Prof. T. G. Halle of Stockholm for the following statement of his present view of this problem :—

" My first hand knowledge of the *Gigantopteris* flora is confined to North China. In 1927 I expressed the opinion that in Shansi this flora is not younger than Middle Permian and may fall entirely within the Lower Permian. Nothing has occurred since then to make me assign a younger age to this flora. We know little of the vertical range of *Gigantopteris* in South China, but judging merely from the fossil plants, I still think that the *Gigantopteris* flora is probably not younger than Middle Permian and may partly—even perhaps entirely—fall within the Lower Permian. I give you this opinion for what it is worth, fully realising that most geologists will let the marine faunas have the deciding vote."[4]

Correlation of the Lopingian with the Salt Range and Russian Permian.

The Choutang Series and the Changhsing Limestone form the lower and upper divisions of the Chinese Lopingian and they were tentatively correlated by Huang with the Middle and Upper Productus Limestones, respectively, of the Salt Range, while the Lopingian as a whole was regarded as the equivalent of the Kama Beds and Tartarian Series of the Upper Permian of Russia. But there is an impressive body of opinion which does not accept these views, which would instead relegate the Choutang fauna, and, as a consequence, the *Gigantopteris* Beds, to the Middle and in some cases to the Lower Permian. If this conclusion is correct, part of the Red Beds might well belong to the Upper Permian, but whether this will eventually prove to be the case still remains to be seen.

[1] *Bull. Geol. Soc. China*, Vol. XIV, No. 4, p. 569, [1935].
[2] *Mem. Geol. Surv. China*, Ser. A, No. 10, p. 58. [1932].
[3] *Ibid.*, p. 62.
[4] In a private letter, dated November 19th, 1937.

According to G. Fredericks, the whole of the Lopingian is to be classified with the Kalabagh and Virgal Beds of the Middle Productus Limestone and with the Chernaya Ryechka Beds of Russia. The latter form the lowest of the three subdivisions of the Kungurian, itself the upper of the two divisions (Kungurian and Artinskian) of the Middle Permian, as defined by Fredericks.[1] (Many Russian geologists of course still place these two divisions in the Lower Permian).

Describing the Permian deposits of the Russian Far East which include limestones with *Lyttonia*, D. F. Masslenikov states that this fauna shows a close resemblance to that of Virgal and Kalabagh, as well as to the Chinese Lopingian and Maokou faunas, adding that. "Its composition indicates Middle Permian age, which corresponds to the upper parts of the Lower Permian by a binominal division of the system."[2]

Prof. J. A. Douglas in his analysis of the relationships between the Chinese, Indo-Iranian and Russian Permo-Carboniferous has suggested an emendation of Huang's correlation, and prefers to classify the Choutang Series with the Artinskian and the Changhsing Limestone with the Kungurian and the Upper Productus Limestone.[3]

Finally, A. W. Grabau regards the Artinskian of Eastern Europe and the Lopingian of China as equivalent, retreatal phases of the same great marine transgression.[4]

It is noteworthy that the *Lyttonia* limestones of the Russian Far East are followed by freshwater, continental beds and Upper Permian shales with coal seams. We may also recall in this connection the occurrences of Red Beds with salt and gypsum in the Kungurian of European Russia, the Kazanian (Upper Permian) Red Beds of the Urals and the Ufa Plateau, the Vetlungian (Lower Trias) Red Beds of the Volga, Dvina and Oka regions as well as the characteristic features of the German Zechstein. "In China too", as Grabau has remarked, "sandstones, often salt-bearing, represent a retreatal and partly emergent phase of the true Permian."[5]

[1] *Bull. Geol. Soc. China*, Vol. XIII, No. 4, p. 546, [1934].
[2] *Abstracts of Papers*: XVII *Internat. Geol. Cong., Moscow*, p. 104, [1937].
[3] *Pal. Ind.*, N. S., Vol. XXII, No. 6, p. 49, [1936].
[4] *Bull. Geol. Soc. China*, Vol. XV, No. 1, p. 43, [1936].
[5] *Ibid.*, p. 43.

Grabau's statement quoted in the preceding paragraph has been elaborated at length in his joint paper with V. K. Ting on the classification of the Chinese Permian, presented to the International Geological Congress at Washington in 1933, but not published until 1936, the year of Ting's lamentable death after a mining accident in Hunan. The earlier section of this paper in which it is shown that even under the earlier classification adopted by Huang and others, a place might still be found within the limits of the Permian for part of the Yunnanese Red Beds, was written before Grabau's and Ting's publication was available in England but is allowed to remain unaltered[1].

A. W. Grabau and V. K. Ting's Classification of the Chinese Permian.

These authors place the whole of the salt-bearing Red Beds of Yunnan and Szechuan in the Upper Permian, mainly as a result of palæontological evidence, not at Huang's disposal, supplied by Prof. Etienne Patte's examination of faunas from Kueichow and elsewhere[2].

Their classification differs from Huang's by regarding his Uralian Series (the Chuanshian, which they rename the Mapingian) as Lower Permian; by raising the Yangsinian from the lower and lowering the Lopingian from the upper division and classifying them together as Middle Permian, and, finally, by creating a new division, the Yehlangian, of Upper Permian age. This Yehlangian Series, known only from South China, is stated to exhibit two distinct regional types; a north-western one confined to Yunnan, Szechuan and North-Western Kueichow and embracing the Lopingian (*Gigantopteris*) coal-bearing series with its overlying limestone and Red Beds—a typical inland basin phase and a south-eastern, contemporaneous open sea phase, developed in South-eastern Kueichow and neighbouring regions.

Huang, it may be recalled, regarded the *Oldhamia* Limestone as the upper limit of the Permian, mainly because of the striking faunal differences between it and the pelecypod beds still higher in the sequence[3], and on page 535 it has already been stated that Triassic lamellibranchs had been obtained from about the middle of the thick succession of red shales and sandstones above the Liupakou Series in Kueichow.

[1] *Rept. XVI Internat. Geol. Cong., Washington,* Vol. I, pp. 663-674, [1936].
[2] *Pal. Sinica,* Ser. B, Vol. XV, Fasc. 2, [1935].
[3] *Mem. Geol. Surv. China,* Ser. A, No. 10, p. 101, [1932].

Prof. Patte has shown, however, that in strata overlying the Lopingian (Upper Permian of Huang) and particularly in the lower parts of the Yulungshan and Tayeh Limestones (Basal Trias of Huang, renamed the Sanchiao Limestone by Grabau and Ting), Palæozoic forms of life still persist. These include a trilobite, a new species of the entirely palæozoic ostracod *Beyrichia*, of the Palæozoic lamellibranch genus *Protoschizodus* together with the Permian form *Pseudomonotis speluncaria* Schl theim. This and other evidence detailed by Grabau and Ting led them to classify these beds, as well as the underlying *Gastrioceras* Shale as Upper Permian.

In addition, they proceed further and classify the Feihsienkuan Series of North Kueichow and Szechuan as Upper Permian. As will be shown later (page 29), part of this series is undoubtedly of Werfenian age, but the horizons from which its fossils were derived lie within its upper portion and their discoverer, Dr. E. Wirth, was unable to decide whether the lower part belonged to the Trias or to the Permian.*

Attractive as this classification is on broad, general grounds, it cannot even yet be taken as really proven that the salt-bearing Red Beds of Central Yunnan are contemporaneous with the fossiliferous Upper Permian of Kueichow.

Plant Beds of the Chennan Chou District.

Reviewing now the evidence bearing on the age of the upper limit of the Red Beds of Central Yunnan, it has been suggested by Saurin that their upper horizons near Lu-fêng Hsien, pass laterally into Coal Measures which have yielded Rhætic or Norian palnt remains. The only other occurrence of this kind known to me in this part of the province, lies between Kaofungshao and Luhokai (Liho), four and eight miles, respectively, to the south-east of Chennan Chou. (Lat. 25°12′ : Long. 101°15′). Here, dark, carbonaceous shales with thin partings of sandstone, black and greyish shales with broken plant remains and thick bands of coarse, white, friable sandstones, occur among typical members of the Red Beds. In an earlier report these were termed, "Deposits of Unknown Age to the East of Chennan Chou."[1] though they are referred to

[1] *Rec. Geol. Surv. Ind.*, Vol. LIV, Pt. 1, p. 84, [1923].

* In a communication entitled :— "Yehlangian : Upper Permian or Lower Trias ?" published after this paper was in print, T. H. Yin has severely criticised the views of Grabau and Ting. See *Bull. Geol. Soc. China.* Vol. XVII, Nos. 3 and 4, pp. 291-300, 1937.

in my field notes as a local variation of a Triassic Red Bed horizon, a doubtful opinion which I preferred not to publish earlier. Possibly they are of similar age and origin to those of Y'u-pi-lang, described by Saurin, but they differ in possessing a high dip of about 40° to the south-south-west.

It is now suggested that both ocurrences bear a close relationship in time to the Coal Measures of the Yunnan-i basin. (Lat. 25°26′ : Long. 100°40′). I have always regarded the latter as of Upper Triassic age, but it is only quite recently that confirmation of this view has been forthcoming. From Yunnan-i itself I obtained a small fauna which by its general facies and the affinities of its species led Dr. Cowper Reed to refer it to the Upper Trias and especially to the Carnian[1]. At Miaotsway, a short distance to the south and from beds somewhat higher in the succession, I found a very abundant fauna, regarding which Dr. Cowper Reed has written :—"If we adopt Krumbeck's recent classification of the Triassic Beds of the East Indies, it seems as if the Miaotsway Beds should be ascribed to the Lower Noric."[2]

Relations with the Coal Measures of Yunnan-i.

Above these beds at Miaotsway follow the Coal Measures of the Yunnan-i basin and although continuous exposures were not obtained, there is no reason to suspect any break in the succession, so that it appears safe to regard the Coal Measures themselves as Upper Norian. A provisional list of the plant remains collected by myself at Miaotsway, based chiefly on determinations by Prof. Sir A. C. Seward, was published by Prof. B. Sahni in 1936. It contains the following forms :—

Equisetites Sarrani (Zeill.)
Dictyophyllum Remauryi (Zeill.)
Tæniopteris Jourdyi (Zeill.)
Dictyophyllum Nathorsti (Zeill.)
Cycadites Saladini (Zeill.)
Pelourdea Zeilleri sp. nov.

It is stated that *Pelourdea Zeilleri* is no doubt identical with Zeiller's supposed *Nœggerathiopsis Hislopi* from Tongking. These fossil

[1] *Pal. Ind.*, N. S., Vol. X, No. 1, p. 244, [1927].
[2] *Ibid.*, p. 203, [1927].

plants from Yunnan were taken to Paris by Prof. Sahni, and thanks to the courtesy of Prof. Painvain of the École des Mines, compared with Zeiller's Tongking types with which they are stated to show unmistakable affinities, and none with the Indian Gondwana flora.[1] This particular Tongking flora, formerly regarded as Rhætic, is now placed in the Norian. Indeed, the Miaotsway section furnishes additional proof that this change is correct.

The Junction of the Fossiliferous Trias of Yunnan-i and the Red Beds.

In an earlier paper I have stated that the fossiliferous marine Trias of the Yunnan-i basin may be faulted against the Red Beds which follow them to the east[2]. The evidence for this consists entirely of changes of dip in isolated exposures across one particular traverse. On another occasion, somewhat further to the south, I was more inclined to regard the change as due to lateral variation, for reddish-purple shales identical with those of the Red Beds proper were found interstratified with the yellow and white marls and soft, white sandstones of the Upper Trias, before the latter gave way entirely to the Red Beds.

Summarizing the evidence advanced in this chapter, it is concluded that the Red Beds in question cannot be older than the Upper Permian and are not younger than the Upper Trias. Attention may now be directed to the Red Beds in Szechuan to the north, Indo-China and Siam to the south, the Federated Shan States and Burma to the west, with a view to their comparison and correlation if this appears to be possible.

III.—THE RED BEDS OF SURROUNDING REGIONS.

A. Szechuan.

As the Cretaceous and Tertiary ages attributed to the Red Beds of Central Yunnan by K. Krejci-Graf and others are based on their likenesses in certain respects with such deposits in the neighbouring, northerly province of Szechuan, further consideration of the latter is warranted here, particularly as it is hoped to demonstrate that the real analogies lie for the most part with certain facies of the Triassic rocks which also occur there.

[1] *Journ. Ind. Bot. Soc.*, Vol. XV, No. 5, p. 328, [1936].
[2] *Rec. Geol. Surv. Ind.*, Vol. LIV, Pt. 1, p. 79, [1923].

The Red Basin of Szechuan and the work of Y. T. Chao and T. K. Huang. (1931).

The great Red Basin of Szechuan occupies an area of not less than 67,000 square miles, bounded, roughly, on the west by the frontier ranges of Eastern Tibet; on the north-east and east by the Tapanshan and the ranges cut by the Yangtse in its gorges between Wushan in Szechuan and I'chang in Hupeh, and on the south by the high mountains about the borders of Hupeh, Kueichow and Yunnan with Szechuan (see Pl. I.). The basin itself is filled with sediments of both marine and continental origin, ranging in age from late Permian to Quaternary; the outer ranges display older rocks still. Y. T. Chao and T. K. Huang group the Red Beds of the Basin together as the Szechuan Series which is described as a thick series of prevailing red rocks, chiefly sandstones and clay shales, lying directly on a coal-bearing group of Jurassic age and overlain by Pliocene and Pleistocene gravels. Numerous open, symmetrical anticlines of considerable linear extension occur, in which the older formations-Jurassic, Triassic and Permian are sometimes found. Otherwise from the published descriptions, the writer's personal observations being confined to the edge of the south-western corner of the province, the surface is entirely covered by Red Beds. The Szechuan Series is divided into three parts. The lowest, or Ts'ienfuyen Formation, 200-400 metres (650-1,300 feet) thick, usually carries a basal conglomerate, followed by yellowish sandstones and shales in which fresh-water molluscs such as *Corbicula* and *Cyrena* have been found; in addition to this, fresh water limestones with *Unio* and *Cyrena* have been met with. This fauna, which is of a Wealdean type, dates the beds fairly accurately as Lower Cretaceous.[1] The Middle Division or Kuangyüan Formation, is 1,000 to 1,400 metres (3,280 to 4,600 feet) thick, concordant on the former and mainly composed of red sandstones and red clay shales with minor bands of yellow sandstone. It is supposed to belong to the Middle Cretaceous though part of it may be of Upper Cretaceous age. Discordantly on the Middle Division follows the Upper or Ch'engts'iangyen Formation, about 500 metres (1,640 feet) thick and distinguished by its massive, coarse, soft red sandstones with intercalations of clay shale and the frequent occurrence of conglomerates or conglomeratic sandstones. Because of the pronounced physical break

[1] Grabau, A. W.: "Stratigraphy of China," Vol. II, pp. 664-5.

separating the Lower and Middle Divisions from the Upper one, the age of the latter (the Ch'engts'iangyen Formation) is regarded as in all probability as Tertiary and it has been placed in the Eocene pending further discoveries.

Chao and Huang state that everywhere this Ch'engts'iangyen Formation is but slightly tilted, the dip being usually from 7° to 15°, whereas the Kuangyüan Formation possesses dips of 30°, 40° or even 70° with sharp anticlines and synclines locally. They add that nine-tenths of the entire area of the Red Basin is the domain of the Szechuan Series and that the middle portion (the Kuangyüan Formation) is the most widespread, indeed, it is possible to travel for days on end across its red clays and sandstones. The lowest portion, on the contrary, is of rather limited extent. These Red Beds weather into a soil which produces crops supporting not less than 50 millions of the Chinese people, and in so doing form a contrast with the Red Beds of Yunnan which are amongst the more thinly populated parts of that Province.[1]

Arnold Heim's Classification. (1930).

Arnold Heim, as mentioned earlier (p. 524), divided the Szechuanese Red Beds into three parts--in descending order the Tshiating, Tshungking and Tseliutsin Series, respectively; names which have priority over those of Chao and Huang. He found no proof of the angular unconformity which these authors had reported between the base of the Red Beds and the underlying Jurassic on the north-western margin of the basin. The "apparent conformity" between the two systems in its interior suggests to him rather a "perfect concordance," if not "a continuity of sedimentation." Moreover, to Heim the whole of the Red Beds are Cretaceous, with high dips even in their youngest exposures.

H. C. T'an and C. Y. Lee's Classification. (1933).

In their reports of the oil fields and salt deposits of Szechuan, H. C. T'an and C. Y. Lee also adopt a threefold division, using two of Heim's terms (with variant spellings) but not within the same limits. A new and uppermost Mengshan formation, 800 metres (2,600 feet) of brown sandstone and shale, with local conglomerates, is distinguished, but it is only of limited extent in the west. They give the aggregate thickness as 2,800 metres (9,200 feet). regard the whole as Cretaceous conformable with the underlying Jurassic,

[1] *Mem. Geol. Surv. China*, Ser. A, No. IX, [1931].

with the possibility that the lowest 100-400 metres (330-1,320 feet) of the Red Beds may be of Upper Jurassic age, while the transition from one subdivision to the next is said to be very gradual.[1] In another paper T'an has stated that both Cretaceous and Jurassic have been folded and tilted together as a single unit.[2] This classification is adopted by Dr. G. B. Barbour in his commendable "Physiographic History of the Yangtze", where a full account of the implications of these structural relations will be found.[3]

G. D. Louderback's Classification. (1935).

G. D. Louderback has proposed another classification of the Red Beds, but has refrained from entering into the "game of nomenclature". Of his four arbitrary divisions, the lowest and the highest are the equivalents of Arnold Heim's Tseliutsin and Tshiating sections, while his divisions II and III are embraced in Heim's Tshungking Series, as is indicated in the following table, adapted from those given by Louderback himself and by Lee.[4]

Comparative Classifications of Formations in the Red Basin of Szechuan.

Louderback, 1935.	Heim, 1930.	Chao & Huang, 1931.	T'an & Lee, 1933.
			Mengshan Formation 800m.
IV.—Bright red and white member	Tshiating Series.	Ch'engts'iangyen Formation 500m.	Chiating Formation 500m.
III.—Red shale and subordinate sandstones.	Tshungking Series.	Kuangyüan Formation 1000-1400m.	Tsuliuching Formation 800-1500m.
II.—Heavy sandstones and subordinate shales.		Ts'ienfuyen Formation 200-400m.	
I.—Limestones with shales and sandstones.	Tzeliutsin Series.		

NOTE.—Tshiating and Chiating (Kiating) are variants of the same name, as also are Tzeliutsin and Tsuliuching. Tshungking is usually written as Chungking. (100 metres=328 feet).

[1] *Bull. Geol. Surv. China*, No. 22, [1933]. see also *Bull. Geol. Soc. China*, Vol. XIII, pp. 91-104, [1934].
[2] *Bull. Geol. Soc. China*, Vol. XVI, p. 399, [1936-7].
[3] *Mem. Geol. Surv. China*, Ser. A, No. 14, pp. 23-37, [1935].
[4] *Bull. Dept. Geol. Sci., Univ. California*, Vol. XXIII, No. 14, pp. 459-466, [1935].

Louderback found no angular unconformity within the Red Beds nor any break between them and the underlying Hsiangchi Series. The plant remains from the latter are generally believed to be Rhætic and though in some localities they have been determined as possibly Liassic, as Louderback remarks, " this still leaves a remarkable gap not yet recognised by direct observation as a definite disconformable or diastrophic break." He was thus led during his field work in Szechuan to the belief that the Red Beds were probably not later than Jurassic. He recalls Chao and Huang's assertion that the fresh water forms of *Unio* and *Cyrena* from the limestone layers towards the base of the Red Beds, are indistinguishable from those found in the Yangtze valley at Litu and in the Kueichow region and determined by Frech and Grabau respectively as Wealden. He mentions that the *Estheria* from about the top of the Ts'ienfuyuen formation (*E. middendorfi* var. *sinensis* and *E. elliptica* var. *intermedia*) are, in Chi's opinion, Lower Cretaceous forms.[1] He states his belief that all the members of the Szechuan Series have been folded together and, finally, he announces his own though not the first discovery of dinosaurian bones near Jung Hsien (29°29′: 104°20′), about one thousand feet above the horizon of the Tzeliuching limestone. This stratigraphic position corresponds to about the middle of the Tshungking Series of Arnold Heim, the top of the Ts'ienfuyuen Formation of Chao and Huang and the middle of the Tsuliuching Formation of T'an and Lee.

Reptilian and Other Remains from the Red Beds.

The fragments of large bones and part of a tooth found by Louderback were examined by C. L. Camp who concluded that they seemed to belong to a huge, carnivorous dinosaur possibly related to *Tyrannosaurus* of the Upper Cretaceous of North America. But there is an addendum reading as follows:—" The Szechuan dinosaur belongs evidently to the *Megalosauridæ*. It is an extremely large, advanced form, but even so it may be Jurassic rather than Cretaceous in age."[2]

In 1935 various fossil teeth from the Tzuliuching Formation were doubtfully referred to some sauropterygian or crocodilian[3] and in 1937 the discovery of numerous fish, crocodilian and dinosaurian bones, including a complete skeleton of the latter, was

[1] *Bull. Geol. Soc. China*, Vol. X, pp. 197-198, [1931].
[2] *Bull. Dept. Geol. Sci., Univ. California*, Vol. XXIII, No. 15, pp. 467-472 [1935].
[3] *Bull. Geol. Soc. China*, Vol. XIV, pp. 67-72, [1935.]

announced by C. C. Young, after special searches made for the purpose with Prof. C. L. Camp.[1] When these vertebrate remains have been described, it may be possible to determine the age of the Red Beds more precisely.

Such in summary outline are the Cretaceous-Tertiary Red Beds of Szechuan with which the Permo-Triassic Red Beds of Central Yunnan have been confused, though in all fairness it must be admitted that geologists previously acquainted with the Red Basin of Szechuan and then finding enormous expanses of unfossiliferous red rocks of similar lithological characters, in the course of rapid traverses across its borders, are hardly to be blamed for regarding them at first sight as identical.

But we must turn to the fringes of the Red Basin of Szechuan in which the older formations come to the surface, and to the evidence supplied by the deep bores of the Tseliutsin field to find their real equivalents. Y. T. Chao divided these Triassic rocks into a lower, Feisienkuan Series, of purple or purplish-red shales, with some thin intercalations of shaly limestone in its upper part, and an upper limestone division, the Chialing Limestone.[2] The same writer and T. K. Huang, added later, that the shales are widely distributed in southern and south-eastern Szechuan, while the overlying limestone beds contain so many purple and yellowish shaly members in their lower horizons that the line of demarcation between the two subdivisions is entirely arbitrary. The limestone too, occurs in all the marginal ranges of the Red Basin.[3]

Triassic Rocks of the Rim of the Red Basin, Y. T. Chao. (1929).

As an example of the extreme difficulty which sometimes occurs in attempts to separate the Red Beds of Triassic and Cretaceous ages, respectively, the following instance taken from Arnold Heim's account of the geology of Omeishan is given. In the neighbourhood of this sacred mountain which lies on the south-western lip of the Red Basin, Triassic rocks are exposed in the Szebaho Gorge.[4] Of a total thickness of 850 metres (2,790 feet), the lowest 200-250 metres, overlying the Permian basalt, are made up of purple clay shales and marls with thin layers of hard green sandstone. Above

The Trias of Omeishan, Arnold Heim. (1931).

[1] *Bull. Geol. Soc. China*, Vol. XVII, pp. 109-120, [1937].
[2] *Bull. Geol. Soc. China*, Vol. VIII, No. 2, p. 143, [1929].
[3] *Mem. Geol. Surv. China*, Ser. A, No. 9, p. 153, [1931].
[4] Omeishan (11,000 feet) lies about 20 miles, as the crow flies, west-south-west of chiating, shown on Pl. I. It is a place of pilgrimage for followers of Buddhism.

these follow 200-250 metres (656-820 feet) of hard sandstone, carrying thin layers of sandy limestone, regularly intercalated with brilliant purple to violet marls. The section is continued upwards with 250 metres of thickly bedded, fine-grained limestone and completed by 80 metres (262 feet) of grey marls which contain marine pelecypods and ammonites in their upper layers. From a collection of the former T. H. Yin has described *Halobia comatoides* sp. nov., *H. omeishanensis* sp. nov. and *Posidonomya* aff. *wengensis* Wiss. which are regarded as Ladinian in age.[1]

On the opposite side of the same fold, nevertheless, where a repetition of the same Triassic sequence might reasonably be expected, a thick series of purple clays, followed by soft sandstones, has been mapped as Cretaceous. Heim points out, however, more than once, that this may be wrong and the beds in question may really belong to the purple Lower Trias. Two visits to the area, in 1929 and 1931, respectively, failed to solve the problem and it is left open for future study with the words "Are the Red Beds of the Omeishan syncline Triassic ?"[2]

Triassic Red Beds of Szechuan, E. Wirth. (1936).

In 1936, Eberhard Wirth published the results of his investigations in Szechuan during which he examined the Triassic deposits of the whole extent of the Red Basin and its borders.[3] He states that the Triassic formations have been mistaken repeatedly for the Cretaceous Red Beds, an error which has led to incorrect interpretations of the geological relationships of some localities.

Dr. Wirth also made a detailed study of the Tzeliuching anticline where deep borings have been made for brine and gas, during the last millenium, over an area measuring about 70 sq. kms. (27 sq. miles). Extracts from some of the logs of the deeper wells are given which show that a maximum depth of 1,300 metres has been reached, traversing the whole of the Cretaceous, Jurassic and upper division of the Triassic formations (the Chialing Limestone) and penetrating a portion of the Feisienkuan Series (the lower division of the Trias).

His general conclusions may be summarized as follows :—

1. The formation of the Red Basin as a subsiding region between rising borders took place in the Permo-Trias.

[1] *Bull. Geol. Soc. China,* Vol. XI, No. 3, pp. 247-254, [1931].
[2] *Geol. Surv. Kwangtung & Kwangsi,* Spec. Pub., XIII, p. 49, [1932].
[3] *Neu. Jahrb. für Min., etc.,* Bd. 73, Abt. B, pp. 412-446, [1936].

2. The greatest thickness of the Trias (1,100m. =3,608 ft.) lies in the middle of the basin: it decreases rapidly towards the west, lessens and finally disappears towards the east, diminishes very quickly towards the north and is entirely absent in the Tsinglingshan. But towards the south, and this is particularly important in connection with the age of the Red Beds of Yunnan, no reduction in thickness has been established. *In other words, the basin was open towards the south and the Trias of Szechuan is continued in the developments of the same formation in Yunnan and Kueichow.**
3. The position of the borders of the basin is marked out by the lithological facies, of which two varieties occur. *One of these is characterised by the occurrence of typical Red Beds, of red and violet shales and this red mud sedimentation is confined to the border regions.* In the centre of the basin, a calcareous development prevails and red sediments are missing.
4. The Triassic basin of Szechuan stands in the same relationship with the Himalayan geosyncline as the Germanic Trias does with the Alpine one.
5. The marine fauna described by Wirth from the Feisienkuan Series contains 50 *per cent.* of forms which are characteristic of the Lower Trias, and its distribution proves that beds of Werfenian age reach up to the base of the Chialing Limestone, that is to say they embrace half of the Trias as it is typically developed in Szechuan. *No fossils have been obtained from the lowest 200 metres (656 feet) of the Feiseinkuan Series and it is therefore still not known whether they really belong to the Trias or, on the contrary, form part of the underlying Lopingian (Permian).* Moreover, the exact position of the Chialing Limestone in the Trias, remains undecided.

It should now be apparent that in spite of the wide-spread occurrence of Red Beds of Cretaceous age in the Red Basin of Szechuan, there is abundant evidence of the existence there of similar deposits of Triassic age as well.

* The italics are mine. J. C. B.

Age of the Salt Deposits of Szechuan.

The Red Beds of the two provinces, Yunnan and Szechuan both contain extensively worked salt deposits, of great importance in local social economy, and it remains to consider the opinions of various authorities on the age of the latter, in so far as they have a bearing on the age of the Red Beds of Yunnan.

A. W. Grabau, quoting Abendanon, places the reddish-brown claystones and sandstones which contain a thin band of rock salt, met with in borings on the Tzuliutsin anticline, in the Trias. In another place he states that the salt wells of Szechuan apparently tap a Permo-Triassic horizon[1].

H. C. T'an and C. Y. Lee, the authors of the official memoir on the salt industry of Szechuan, admit that the only rock salt horizon, a seam which is but 2-5 metres (6½-16½ feet) thick, extending over an area of about 64 sq. kms., (24½ sq. miles), occurs 270-300 metres (885-984 feet) below the top of the Triassic limestone. They point out, however, that brines are won from Triassic, Jurassic and Cretaceous horizons and advance the hypothesis that the rock salt was derived from the brines of these higher horizons. The salt solutions, they imagine, acquired increased salinity by gradually sinking through successively deeper saliferous layers, until, supersaturated, their content was precipitated in cavities of the Triassic limestone.[2]

These views are not shared by the majority of their Chinese colleagues. Dr. W H. Wong, Director of the Geological Survey of China, for example, states :—" I for one believe that the salt was originally contained in the Triassic at least."[3] Dr. E. Wirth is equally emphatic :—" The salt in the Trias of Szechuan is certainly primary. There is no possibility of explaining it by later immigration from younger salt-bearing beds."[4]

We see then that the latest available evidence proves that the Triassic basin of Szechuan was open to the south into Yunnan and Kueichow, and if it is admitted that the meagre rock salt deposits of Szechuan are of Triassic age, it is probable that those of Central Yunnan and perhaps of other parts of the province too, represent similar, if not intensified conditions of deposition operating at much the same time.

[1] " Stratigraphy of China ", Vol. 11, pp. 27 and 42.
[2] *Bull. Geol. Surv. China,* No. 22, p. 76, [1933].
[3] *Ibid.*, p. 75, (footnote).
[4] *Neu. Jahrbuch für Min, etc.*, Bd. 75, Abt. B, p. 425, [1936].

B. French Indo-China.

Late Mesozoic Continental Formations.

Geological maps of Indo-China show much of its western and southern parts covered by a formation usually referred to by French writers as "Les Grès supérieurs", "Les Grès continentaux", or simply as "Le Revêtement posttriassique". A long band stretches completely across the Upper Laos, between the frontiers of the Southern Shan States and Siam on the west and the Mekong on the east, with various extensive outliers to the north-west and south-east. Large isolated patches continue down the Mekong valley, from the neighbourhood of Vientiane until, coalescing in the Lower Laos, they mantle the whole country between the Central Chain and the Mekong and surround the basalt plateau of Boloven. These exposures are continuous with those of Cambodia, where the formation builds practically the whole of the higher ground which wraps around the central plain with its great lakes. Remnants of the covering are also found in the eastern parts of the territory, particularly in Cochin China and Southern Annam, and, again, far to the north, where there are patches on both flanks of the delta of the Red River in Eastern Tongking. As a general rule the formation consists of red or grey sandstones, sometimes containing a little salt in their more northern exposures, with beds of conglomerate and red, shaly clay. It is often very thick, as for example in the Mekong valley where it is estimated at over 1,000 metres (3,280 feet). For the main part horizontal and undisturbed, yet undoubtedly discordant on the Trias in its clearest sections, a Rhætic or Jurassic age is generally attributed to it. This is confirmed by the presence of *Otozamites latieri* in Eastern Tongking, of *Goniomya bisinuata* Mans. in a red conglomeratic sandstone of the upper part of the Red Beds of the Northern Laos and by the fact that in the Lower Laos sandstones and red shales pass locally upwards into Hettangian marls with *Polymorphites Jamesoni*.[1]

Cretaceous Red Beds in the Lower Laos.

'The recent discoveries of J. H. Hoffet in the Lower Laos of red sandstones and "terrain rouge" containing bones of the Senonian dinosaur *Mandchurosaurus* together with those of *Titanosaurus* and various species of lamellibranchs, belonging to the genera *Trigonoides* and *Plicatounio* lead to some extension of the previously accepted

[1] *Bull. Soc. geol. France,* 5th Serie, 4th Vol., pp. 110, 137, 142, 143, (1934).

upper limits of the beds just described, and also entails a modification of existing ideas of the distribution of land and sea in Indo-China and Siam at the close of the Mesozoic era. These Senonian rocks lie above another group, described as "Grès et Poudingues supérieurs" with "terrain rouge", and sandstones with intercalations of limestones containing Liassic fossils. They are brackish and lagunary formations believed to have been deposited on the borders of a marine gulf, the limits of which are broadly defined in M. Hoffet's papers.[1]

Red Beds of Triassic age.

While it cannot be doubted that the Red Beds of Upper Mesozoic age cross the Laotian frontier into Southern Yunnan and probably into the Southern Shan States, just as it would be idle to deny that the Cretaceous rocks of the Red Basin of Szechuan may not cross for some small distance into Northern Yunnan, it is not with such formations that the folded, rock salt-bearing Red Beds of Central Yunnan are to be compared. In Indo-China, as in Szechuan, a lower series of Red Beds of Triassic age exists and it is amongst these that our true homologues are to be found. J. Fromaget has summarized the lithological types of the Indo-Chinese Trias as follows:—"The Triassic facies vary with the position and with the age of the sediments. Detrital deposits, arkoses, conglomerates, with or without "terrain rouge", are abundant at the base of the Trias and in all the littoral sediments of the period; at the top they mark the passage into the lagunary regime of the Rhætic and of the Lias. Shales of a more or less sandy character and sandstones with Myophorias occur on the edges of the marine depressions, the axes of which are occupied by shales and limestones with cephalopods, brachiopods, gasteropods and more rarely, anthozoa".[2] Describing the continental Rhætic, Liassic and Jurassic deposits it is shown that they only continue a set of conditions already initiated in Triassic times, the sandy deposits of which, of a reddish facies, are well known.[3]

In cases, therefore, where the younger "terrain rouge" displays the same lithological characters as the Triassic rocks themselves,

[1] *C. R. Ac. Sc.*, Tome 202, No. 22, pp. 1867-69, (1936).
Ibid. Tome 204, No. 19, pp. 1439-41, (1937).
Bull. Serv. géol. Indo-Chine, Vol. XXIV, Fasc. 1, (1937).
[2] *Bull. Serv. géol. Indo-Chine*, Vol. XIX, Fasc. 1, p. 17, (1931).
[3] *Ibid*, p. 22.

it is not surprising to learn that the relations of the two groups are far from being distinctly clear, everywhere.[1]

The great extent to which such red, sandy formations occur in the Trias of Indo-China, is perhaps somewhat over-shadowed by the intensive studies which French geologists have rightly devoted to the elucidation of their marine equivalents with their abundant faunas, but a consideration of such tables as Fromaget's "Essai de Synchronisation des Formations géologiques dans le Nord de L'Indo-Chine centrale"[2] or of the same writer's "Résumé de la Répartition des Indosinias"[3], will show that they are to be found in most parts of the country from Cochin China and Cambodia in the south, to Western Tongking and the Northern Laos at the other extreme. Only two cases can be briefly dealt with here, from Central Annam and the Northern Laos, respectively.

Continental Trias of Central Indo-China.

Prof. Jacob has described how from the latitude of Hué on the eastern side of the Annamite Cordillera, northwards as far as Vinh (a direct distance of approximately 190 miles) and following the coast, even as far as Thanh-hoa (a further 80 miles), the Trias is represented by conglomerates, sandstones and red clays, sometimes with coal seams as at the locality of Ha-tinh. Throughout this region it consists of an unfossiliferous, transgressive complex which further to the north-west still, passes into another folded complex of clays. reddish-purple shales and subordinate sandstones, described by Ch. Jacob and L. Dussault as occurring in the Tran-Ninh region of the Laos.[4]

North of Vinh, in the Hoang Mai district, though the Lower Trias still consists of conglomerates and red sandstones, fossiliferous marine deposite of Virglorian and Ladinian age occur but further west towards the Annamite Cordillera, these once more pass laterally into sandy shales and red clays.

Red Beds of the Upper Laos.

In the Upper Laos, west of the Nam On valley, owing to the plunging of the prevailing anticlinal structures towards the north, the surface mantle of the "grès rouges salifères", comes eventually to outcrop over the greater part of the extreme north-west and, as Prof. Jacob has foreseen, probably extends into the Southern

[1] Géologie et Mines de la France d'outre mer: p. 417, (1932).
[2] *Bull. Serv. géol. Indo-Chine*, Vol. XVI, Fasc. 2, (1927).
[3] *Bull. Soc. géol. France*, 5th Ser., Vol. IV, (1934).
[4] Géologie et Mines de la France d'outre mer: p. 410, (1932).
[5] *Bull. Serv. géol. Indo-Chine*, Vol. XVI, Fasc. 2, fig. 20, (1927).

Shan States and into Southern Yunnan.[1] In the Nam On valley itself and particularly at Phong Saly, a series of shales with thin coal seams has yielded a flora which although containing Rhætic forms is made remarkable by the abundance of other archaic species and these have led to its being placed in the Norian. These plant beds are the lateral equivalents of the base of the local Red Beds, the lower portions of which are consequently believed to be of the same age. The lowest members of the Red Beds are generally red clays with red or white sandstones and above them follow thick beds of red sandstone alternating with thin layers of clay. Green layers, or more frequently green stains, as well as beds of pebbles also occur, especially towards the base. The formation is salt-bearing but the salt is only found in impregnations which seem to be more abundant or even localised in the lower argillaceous parts. The red sediments are nearly horizontal and no discordance breaks the monotony of their stratification, nevertheless, in descending the series, a more and more marked tendency to folding developes, a phenomenon already met with in the Upper Red Beds of Central Yunnan. The formation has only yielded two fossils, the first a phyllopod, *Estheria Zeilli* Mans., which Mansuy considered as extremely close to *E. mangaliensis* Rupert Jones, of the Wardha-Gondwana basin of the Indian Peninsula, which occurs in the salt-bearing clays of the base; the second, *Goniomya bisinuata* Mans. from a conglomeratic red sandstone of the upper part of the Red Beds. J. Fromaget has discussed this fossil and concludes that its horizon is to be placed in the Rhætic, with the admission that the formation of the Red Beds could have continued into the Lias and even beyond.[2]

There is thus some correspondence between at least the lower part of the Laotian Red Beds and the upper horizons of the Red Beds of Central Yunnan, but this does not complete the analogy, for there is more than a suspicion of an age relationship between slightly older groups in both regions, as will now be seen.

The Luang Prabang Dicynodon.

Above the fossiliferous Upper Permian rocks of the Luang Prabang neighbourhood and particularly at Pou Say, there follows a series of variegated clays, often full of pebbles of *Fusulina* limestone, above which successively and concordantly come red, argillaceous

[1] *Bull. Serv. géol. Indo-Chine*, Vol. XIII, Fasc. 4, p. 64, (1925).
[2] *Bull. Soc. géol.* France, 5th Ser., Vol. IV, pp. 110, 142, (1934).

sandstones and green, quartzose sandstones, passing by weathering into white and rose tints. From a band of green sandstone immediately above the variegated clays a reptilian skull was obtained by H. Counillon in 1892.[1] It was described by J. Repelin in 1923 as *Dicynodon incisivum* and compared with *D. orientalis* Huxley from the Panchet Series of the Indian Gondwanas.[2] If this comparison may be taken as a criterion of age then the beds from which this vertebrate comes are to be regarded as belonging to the Lower Trias, though to J. Fromaget they are the lateral equivalents of marine Carnian-Norian and Norian horizons.[3] P. L. Yuan and C. C. Young, however, state that "*Dicynodon*" *incisivum* is clearly referable to *Lystrosaurus*, adding that Huxley's *D. orientalis* from the Panchets is probably also a member of the same genus.[4] On the other hand, J. Piveteau, who has made the most recent examination of the Luang Prabang skull, identifies it with the South African *Dicynodon lacerticeps* Owen.[5] In spite of these conflicting opinions it is not apparent that any change need be made in the presumed Lower Triassic age of the specimen.

Summarizing this brief review, it is seen that in addition to "Les Grès supérieurs" of Rhætic or post-Rhætic age and of "Les Grès inférieurs" or "Terrain rouge inférieur", usually assigned to the Norian, there is incontestable evidence of the existence in various parts of French Indo-China of still lower horizons of Triassic Red Beds (in spite of the frequency of lateral marine facies), with which the lower parts of the folded Red Beds of Central Yunnan may properly be compared.

In a résumé published while this paper was in the press, J. Fromaget has divided the enormously thick covering of continental, lagunary and subcontinental deposits (the Indosinias) of Central Indo-China, as follows :—

1. A Lower Series of sandstones and effusive rocks, dating from the end of the Hercynian phase to the Carnian.
2. A Middle Series constituting the "Terrain Rouge Inférieur" which, in general, comprises two elements: one versi-

[1] *Bull. Serv. géol. Indo-Chine*, Vol. XIII, Fasc. IV, p. 55, (1924.)
[2] *Bull. Serv. géol. Indo-Chine*, Vol. XII, Fasc. II, (1923).
[3] "Contribution á l'étude structurale du sud-est de l'Asie.", p. 15, (1934).
[4] *Bull. Géol. Soc. China*, Vol. XIII, No. 4, p. 580, (1934).
[5] *C. R. Soc. géol. France*, Fasc. 6, pp. 70-72, 15th March, (1937).

coloured and rather argillaceous; the other chiefly red and usually sandy; it ranges from the Carnian to the Norian.

3. An Upper Series particularly abundant in red and white sandstones, mainly of Liassic age but extending into the Cretaceous in places.

This threefold division of the Indosinias is also adopted on recent geological maps of French Indo-China.*

C. Federated Shan States.

The Namyau Series.

In the preceeding number of these "Contributions", the Red Beds of the Northern Shan States, the Namyau Series, were discussed at length, more particularly as regards the identity of certain limestone horizons which they contain with the Liu-wun Brachiopod Beds of Western Yunnan and their alleged relationships with the Norian Brachiopod Beds of Northern Indo-China. At the same time a plea was made for an examination of the lamellibranchs from the Namyau limestones, in the hope that they might furnish better evidence of age than that based entirely on earlier studies of their brachiopod fauna.[1] Unknown to the writer such an investigation was actually in progress then and Dr. F. R. Cowper Reed has now published descriptions of numerous lamellibranchs from two separate calcareous horizons in North Hsenwi. His paper must be consulted for details, but it may be noted here that one horizon is identical with other well known outcrops in North Hsenwi and Hsipaw and with the Liu-wun Brachiopod Beds, while its fauna suggests a Cornbrash rather than a Callovian or Lower Oxfordian age. The lamellibranchs of the second horizon indicate a Bathonian age.[2] Thus the earlier view that these limestones belong to the Upper rather than the Middle Jurassic has to be abandoned, and Buckman's original opinion on the age of the brachiopods is now no longer in conflict with the results of Dr. Cowper Reed's researches on the lamellibranchs.

* "La Chronique des Mines coloniales", Vol. 7, No. 73, p. 144, (1938).
[1] *Rec. Geol. Surv. Ind.*, Vol. 71, Pt. 2, p. 203, (1936).
[2] *Ann. and Mag. Nat. Hist.*, Ser. 10, Vol. XVIII, pp. 1-28, (1936).

Dr. M. R. Sahni has criticised the proposal of certain French geologists to lower the Namyau and Liu-wun limestones down to the Norian, and concludes as follows :—

"Dr. Reed's description of the lamellibranchs, however, leaves no doubt as to the Jurassic age of at least part of the Namyau Series, and confirms the broader conclusions arrived at from a study of the brachiopods alone from the same series elsewhere. The Norian-age theory of the Namyaus and Liu-wun Beds can, therefore, hardly be maintained, even on the evidence of the lamellibranchs, whose investigation Dr. Coggin Brown has rightly advocated ".[1]

This more exact determination of the proper position of certain limestone bands of the Namyau Series, does not, in my opinion, finally settle the question of the age of the whole of the Red Beds of the Northern Shan States. The total thickness occupied by such calcareous horizons is insignificant in that of the whole ensemble, moreover, the division of the latter into two sections is a suggestion unsupported by any stratigraphical evidence, while the separation of an upper portion as the "Namyau Shales" will bear no critical examination in the field.[2] The "shales", more often than not, are thin bands of red clay, occurring here and there, through several thousands of feet of what is essentially a great sandstone formation. How much of this is older, or what amount is younger than the Middle Jurassic, has still to be determined.

The Red Beds of Kalaw.

The Red Beds of Kalaw were also dealt with in the same earlier contribution, and, it only remains to add that as reconnaissance surveys have been extended, similar rocks have been identified in other previously unknown parts of the Southern Shan States. In the west V. P. Sondhi found them, as anticipated, further down the Panlaung Valley while he has also reported them from the extreme east, in the area lying between Kengtung and the Siamese frontier[3]. No new evidence bearing on their age is forthcoming, though the publication of Dr. M. R. Sahni's paper on the supposed Cretaceous cephalopods has decided this palæontological problem.[4] Yet there is still a possibility that both Kalaw Red Beds and Namyau Series might range into the Cretaceous period. For the moment, the former may be regarded as Rhætic or younger.

[1] *Rec. Geol. Surv. Ind.*, Vol. 71, Pt. 2, p. 220, (1936).
[2] *Rec. Geol. Surv. Ind.*, Vol. 71, Pt. 2, p. 228, (1936).
[3] *Rec. Geol. Surv. Ind.*, Vol. LXIX, Pt. 1, p. 59, (1935).
[4] *Rec. Geol. Surv. Ind.*, Vol. 71, Pt. 2, pp. 166-169, (1936).

D. Siam.

It is well known that the salt-bearing "terrains rouges" of the Mekong Valley of the French Laos stretch to the west into Siam. Prof. Jacob, for example, recalls Capt. Cupet's observations on the numerous salt efflorescences between Nongkai and M. Lakhon and how they are found sporadically still farther towards the south and perhaps to Korat.[1] The statements of various geologists who have made traverses in Siam across these rocks will now be summarized.

Captain Cupet's Observations.

Bertil Hogböm describes the formation as a mighty series of red sandstones, conglomerates, red and violet shales and thin limestone bands which attain their greatest extension on the Korat Plateau, continuing east into the Lower Laos and south into Cambodia. Brine springs and salt efflorescences are said to be as characteristic of these rocks as their red colour. While they are nearly horizontal, or only slightly folded, over the greater part of the Korat Plateau, in its north-western corner, to the east of Utaradit and in northernmost Siam generally, the Red Beds have been affected by strong movements. Hogböm designated the age of the formation as Trias, though, as usual, there is no direct evidence of this. He adds, "I also encountered sandstones of obviously Triassic age where the Meping River enters the vast limestone highland south of Chieng Mai. These sandstones lie conformably on the Permo-Carbonian formation and have been seized by the same gentle flexures".[2] It is clear from Hogböm's work that two distinct red formations occur in Siam as they do in the Laos to the east.

Bertil Hogböm, 1913.

From Muang Fang, a town in the extreme north of Siam, about 20 miles from the border of the Southern Shan States, Wallace Lee has described sandstones alternating with red shales, red clays and limy clay shales with a basal conglomerate resting on granite. Fossils collected near Chieng Rai, some 40 miles farther east, were regarded by the United States Geological Survey as of Triassic and probably of Middle Triassic age.[3]

Wallace Lee, 1923.

[1] *Bull. Serv. géol. Indo-Chine,* Vol. XIII, Pt. IV, p. 93, (1925).
[2] *Bull. Geol. Inst. Upsala,* Vol. XII, p. 108, (1913-14).
[3] "Reconnaissance Geological Report of the Districts of Payap and Maharashtra, Northern Siam". State Railways Department, Bangkok, p. 5, (1923).

Wilhelm Credner, however, after his early travels in Siam, concluded that in all probability the folded Red Beds are to be placed in the younger Mesozoic. He continues as follows:—"But besides these strongly folded Red Beds, which represent a continuation of the "terrains rouges" of the French geologists in Indo-China, unfolded, horizontal Red Beds are found in the spacious region of the Korat Plateau, which in the north-west of this area, appear to overlie the older, folded rocks discordantly. Hogböm also extended to these the adoption of a Triassic age, in which, however, we are unable to follow him. These young Red Beds are separated from the older ones by a sharp discordance and between the deposition of the two, the Himalayan folding intervened. The younger group is therefore probably to be placed in the Middle or Late Tertiary".[1] It was indeed these conclusions in the case of Siam which confirmed Credner's acceptance of similar ages for the Red Beds of Central Yunnan. B. Hogböm, however, did not believe that the Himalayan folding affected Siam, for he wrote. "It must be suggested that the Himalayan folding systems have not reached Siam"[2] and, again, "Cambodia with the neighbouring great Korat Plateau is evidently the massif that has remained longest undisturbed, *viz.*, from the Triassic period".[3]

Wilhelm Credner, 1930-35.

In a note embodied in Dr. Oskar Weigel's account of the Sapphire Deposits of Bo Ploi, Credner writes of a formation, probably of Mesozoic to Tertiary age, which is wide-spread in Eastern and North Eastern Siam and extends from Indo-China into South China, where it occupies enormous areas in Kwangtung, Kwangsi, Yunnan and Szechuan.[4]

Credner made several expeditions in Siam and his final views find their expression in a "Systematic Arrangement of the Formation Sequence" given in his important work on the geography of that country. In this scheme both red formations are placed in the Mesozoic; the upper, unfolded one, distributed mainly on the Korat Plateau, with the proviso "age indeterminable, probably young Mesozoic"; the older, folded group, occurring east of the

[1] *Mitt. Geog. Inst. Sun-Yatsen Univ.*, Canton, Vol. I, No. 2, p. 52, (1930).
[2] *Op. cit.*, p. 108.
[3] *Op. cit.*, p. 109.
[4] *Wissenschaftliche Ergebnisse meiner Forschungsreisen in Ostasien*, Heft 1, p. 8, (1934).

highlands of Northern Siam and north-west of the Korat Plateau, as probably Triassic. Both formations are stated to be saliferous.

"The thickness of the beds", writes Credner, "is very great; their distribution unusually varying, so that while in Northern Siam they are intensively folded, in the French Laos they lie almost undisturbed. In the Korat Plateau region of Eastern Siam they also rest entirely in even undulations. The deposition of this thick series which was laid down partly before, or during the last epoch of folding and partly after it, appears to have extended over a very long period of time. We know that in the case of South China it reaches from the Trias to the Late Tertiary and an equally long duration for its formation is quite possible in the case of Siam, but it is not yet proved".[1]

Another point in Credner's latest work which has a bearing on his recognition of the view that the Red Beds of Siam are, at least in part of Triassic age, may be mentioned. He states that the limestones which characterise the Trias of the Islands of the Malay Archipelago are wanting in the Peninsula, where the predominantly argillaceous marine deposits of the Malay States form a transition to the terrestial red sandstones which represent it in continental Siam.

Drs. Arnold Heim and Hirschi, 1935.

Finally, Drs. Arnold Heim and Hirschi surveyed large areas in Siam in 1935. Their results have not been published, but I am permitted, through the courtesy of Dr. Heim, to state that the normal succession of strata in the meridional ranges of North-Western Siam is the following:—

1. Permian limestones with rare *Fusulinidæ*, separated by an unconformity from:—
2. Some 1,000 metres of a formation comprising chiefly greenish, siliceous shales, with rare pelecypods (*Daonella*) of Middle Triassic age.
3. Red Beds, commencing with conglomerates, probably of fresh water origin and containing nodules of limestone. Total thickness over 1,000 metres (3,280 feet).

These Red Beds which are regarded as Upper Triassic to Liassic in age, were found all over Northern and North-Western Siam, as

[1] "Siam: das Land der Tai", pp. 12-13 and 19, (1935).

far as the Burmese border to the west of Raheng, which lies about the same latitude as Thaton in Lower Burma.[1]

E. Lower Burma.

The Red Sandstone Series of Eastern Amherst.

G. de P. Cotter, in 1921, found that the Red Beds of North-Western Siam cross the valley of the Thaungyin River into the eastern parts of the Amherst district of Lower Burma. They lie east of the crystalline rocks of the Dawna Range and are separated from the underlying Kamawkala Limestone by an unconformity.[2] This limestone yielded a badly preserved fauna, the investigation of which by various specialists led the late Prof. J. W. Gregory to the following conclusions :—" Only the Upper Trias and not more than the Carnian and the Norian, are represented in the collection. So far as the evidence goes it suggests that the Lower and Middle Trias were not present in this area ". He compared these conditions with those in parts of Northern Yunnan traversed by himself, where the Upper Trias contains corals and brachiopods and the Lower Trias is continental.[3]

Cotter states that the typical and most predominant rock of the Red Beds is a pink or brick-red to purple sandstone, of fine to medium grain and often pebbly. Associated with it are clays, varying in colour from grey to cherry-red, bands of conglomerate and sandstones of a buff tint. These clays sometimes contain thin layers of argillaceous limestone, about 1 to 3 inches thick, which show traces of fossils in certain localities. These are unfortunately unidentifiable with the exception of an *Astarte*, " not unlike some of the Jurassic species ". Both sandstones and clays frequently exhibit steep or even vertical dips. The presence of red sandstone boulders, as well as limestone, in what appears to be a basal conglomerate resting on the Kamawkala Limestone is puzzling and the derivation of its sandstone is unknown. For the time being, it and other conglomerates are grouped with the red sandstone, with the suggestion that they may be of later date or at least form high horizons in the Red Sandstones. Cotter regarded these Red Beds as of probable Jurassic age and added the following remarks on the problem of their correlation :—" Enough has been said to show the

[1] Personal Communication.
[2] *Rec. Geol. Surv. Ind.*, Vol. LV, Pt. 1, pp. 273-313, (1924).
[3] *Rec. Geol. Surv. Ind.*, Vol. LXIII, Pt. 1, pp. 155-167, (1930).

probability that these Red Sandstones are to be correlated broadly with those of the Northern Shan States, Kalaw, and of Siam and Tongking. May we add also with those of Mergui ? There is no fossil evidence for this last correlation which although very possible is at present quite unproved ".[1]

The Red Sandstones of the Mergui Coast.

The Red Beds of the Mergui Coast and its innermost islands, stretching north-north-west and south-south-east for a distance of 43 miles in a straight line from Canister Bank to Mergui Island, in a series of isolated exposures, mainly but not entirely separated from the mainland by sea or mangrove swamp, were described by the late Rao Bahadur Sethu Rama Rau.[2] He divided them in descending order as follows :—

IV. Purple sandstones, shales and conglomerates.
III. Fine-grained, pinkish sandstones and shales with patches of white clay.
II. Calcareous sandstones.
I. Conglomerates and grits.

The conglomerates and grits are confined to Pataw and Patit Islands near Mergui itself. The lateral variation in the nature of the sediments, and the fact that they contain fresh felspar and pebbles of quartz and slate which have not been carried far, led to the conclusion that the rocks had been derived from the disintegration of the local granite and slates. Near Mergui they rest on the denuded edges of the argillites of the series with the same name, and, here as elsewhere, they are gently folded with angles of dip not exceeding 20°. Regarding their age Sethu Rama Rau wrote as follows :—" Although direct fossil evidence was not obtained in the Mergui district, the author thinks that the Red Sandstone Series of this district forms a link in the chain of outcrops extending from the Northern Shan States to Tongking and Siam, and may probably be of the same age, *viz.*, Jurassic."

The red sandstones are known to contain silicified wood in places, particularly in the quarries of Patit Island, and in this respect they bring to mind the sandy Red Beds of the Bas Laos which are believed to be of Rhætic—Liassic age.[3] Until the Mergui occurrences, however,

[1] *Op. cit.*, p. 283.
[2] *Mem. Geol. Surv. Ind.*, Vol. LV, Pt. 1, pp. 18-19, (1930).
[3] *Bull. Serv. géol. Indo-Chine*, Vol. XX, Fasc. 2, pp. 96-97, (1933).

have received specialised palæobotanical investigation, it is unwise to speculate on their age or relationships.

IV. PALAEOGEOGRAPHY OF THE YUNNANESE REGION IN PERMO-TRIASSIC TIMES.

The Yangsinian Transgression.

The highest undoubted Permian rocks underlying the Red Beds of Central Yunnan contain the *Neoschwagerina craticulifera* fauna and are thus of Yangsinian age. Whatever divergence of opinion may exist about its exact position in the Permian System as a whole, unanimity prevails that it is a transgressive formation, often unconformable on older beds. At the end of the preceding epoch, the Chuanshanian, or Uralian, in the usually accepted meaning of the term, of Huang, renamed the Mapingian and elevated to the Lower Permian by Grabau, the sea had almost completely withdrawn from the southern Chinese basin, though not perhaps from the whole of Indo-China or the Shan States. Its readvance was slow, for the basal beds of the Yangsinian, here and there, contain sandstones and shales with thin coal seams. It is possible that the examples which I described from Siyang (Lat. 25° 6′ : Long. 103° 9′) in Eastern Yunnan, as Moscovian, really belong to the Chihsia Series of the Lower Yangsinian, because of the occurrence in the vicinity of *Michelinia siyangensis* Reed, one of its characteristic fossils.[1] The coral fauna is remarkable and one distinguishing genus, *Tetrapora*, has not been found outside China, with the probable exception of the Southern Shan States, though several of the others, in many cases specifically identical, have been described recently from South-Western Iran by Prof. J. A. Douglas.[2]

The Yangsinian transgression reached its maximum in Chihsia times and extended over practically the whole of South China, though not across certain islands in the south-east and about the Hunan-Szechuan-Kueichow borders. Northwards it stretched to the foothills of the Tsinlingshan, considerably beyond the limits of its Carboniferous and Permian predecessors.

The recession of the Yangsinian sea appears to have been a slow process and while regions covered in the east and perhaps in the

[1] *Rec. Geol. Surv. Ind.*, Vol. XLIV, p. 103, (1914).
Pal. Ind., N. S., Vol. X, No. 1, pp. 83-84, (1927).
[2] *Pal. Ind.*, N. S., Vol. XXII, No. 6, pp. 14-27, (1936).

far west were laid bare, active deposition still proceeded in central and south-western China generally, particularly in Szechuan, Western Kueichow and the greater part of Yunnan, resulting in the formation of the thick Maokou Limestones which are conformable with the underlying Chihsia Limestone. The former carry the highly developed fusulinid fauna with *Neoschwagerina*, *Doliolina*, *Verbeekina* and *Sumatriga*. The known western limits of this fauna in Yunnan lie in the Mekong basin, where it was recognised by von Loczy and by Gregory in the north and by myself in the far south.

The Lopingian Regression and the Yunnanese Basic Rocks.

Overlying these Yangsinian Limestones is the Lopingian Series and in South-Eastern China the two are disconformable; in the middle Yangtze Valley, on the other hand, no disconformity has been reported, but in the region of more immediate concern here, the Yangsinian Limestones are followed by vast thicknesses of volcanic rocks of subærial origin. Thus we are led to deduce a complete withdrawal of the sea from parts of Yunnan and Southern Szechuan and from a smaller portion of Western Kueichow, where the eruptive rocks extend, followed by uplift and long-continued denudation preceding these outbursts. This is the impression remaining in my mind after several traverses across the affected regions in Yunnan and Szechuan, but some observers, particularly Arnold Heim, advocate a submarine origin for the basic rocks. On the edges of the vast area covered by the flows, as for example in the Mekong and Salween (?) valleys in the west and in western Kueichow in the east, this may possibly be the case, but not elsewhere. Chinese writers give the thickness of the volcanic rocks as approximately 500 to 1,000 feet in Eastern Yunnan, 2,500 feet in Northern Yunnan and 4,000 feet near the great bend of the Yangtze. In the north-west it diminishes again to about 500 to 800 feet.

The Lopingian Liupakou Series and the Gigantopteris nicotinæfolia Flora.

Lying above the basic rocks in North-Eastern Yunnan, about the Yunnan-Kueichow borders and in some parts of Western Kueichow, or directly on the Yangsinian Limestones further east still, are the Lopingian sandstones, shales and coal seams with the *Gigantopteris nicotinæfolia* flora (the Liupakou Series). Minor bands of cherty limestone sometimes occur in, amongst, or above the coal measures, carrying the Loping fauna with *Lyttonia* and *Oldhamia*. Grabau and Ting have pointed out

how the marine intercalations of the Lopingian disappear about Long. 106°E, where the series becomes entirely continental, while further west still, about 103° 30′E, the coal measures themselves and their characteristic flora abruptly finish.[1] (See Pl. I.) As is indicated earlier in this paper this is about the line where the basic rocks are overlain directly by the Red Beds. East of this narrow zone of some 2½° of longitude, the land was subjected to shallow, intermittent flooding by the sea. Grabau and Ting explain the absence of the *Gigantopteris* flora in Central and Western Yunnan by its inability to cross the great basaltic highlands which then occupied these regions, an explanation which is unacceptable to the palæobotanist Prof. B. Sahni.[2]

A remarkable feature of the Lopingian sea is that although it carried the typical Indo-Pacific *Lyttonia* fauna and brought the Shan-Chinese area into communication with the Himalayan geosyncline, perhaps by means of a waterway passing through Western Yunnan, Western Szechuan and Eastern Tibet, on the one hand and with Indo-China and Malayasia on the other, it was at the same time, shallow, fluctuating and inconstant. Thus *Giganopteris nicotinæfolia* and its associated plants came to flourish on the tidal flats and coastal swamps around large islands, themselves liable to innundation and submergence from time to time. The involved shore lines of such transient lands washed by a sea which nowhere appears to have attained a great depth and which was constantly receiving clastic detritus in abnormal quantities, in a period and in a region distinguished alike by their general instability, are peculiarly difficult to determine, though Huang has ventured to outline three principal coastal plains over which the *Gigantopteris* flora was spread.[3]

Character of the Permian Transgression in French Indo-China.

Turning now to Indo-China, the French geologists maintain that the sea level oscillated constantly throughout the duration of the Anthracolithic period, but only two main transgressions are at present recognised. The first, of short duration, following an earlier complete emergence of the land, commenced in the Upper Moscovian and was soon followed by a regressive pulsation, so that by Middle Uralian times, outside the Laotian geosyncline on the western side

[1] *Rept. Internat. Geol. Congress*, Washington, 1933, Vol. 1, p. 669.
[2] *Journ. Ind. Bot. Soc.*, Vol. XV, No. 5, p. 326, (1936).
[3] *Mem. Geol. Surv. China*, Ser. A, No. 10, Pl. VI, (1932).

of the Annamite Chain, where marine conditions appear to have been maintained up to the end of the Permian, most of Indo-China was occupied by lagoons and islands, often the scenes of widespread eruptions of porphyrites, dolerites and andesites.

Then followed the more extensive Upper Uralian-Permian transgression, abruptly at first and more progressive afterwards, covering the greater part of Indo-China but leaving unsubmerged various relics of the old massifs; to the north and west, large parts of Yunnan, the Shan States and Siam were flooded, while further south its fossiliferous deposits have been found in the Malay States and the whole of the central border of the Archipelago almost as far east as Serang. In the geosynclinal areas immense thicknesses of limestones occur but rocks of a neritic character are common elsewhere, while continental or lagunar formations are remarkable for their abundance of felspathic sandstones, sandstones, arkoses, conglomerates, shales, marls and carbonaceous shales which often contain intercalations of volcanic rocks usually of a rhyolitic character. These rhyolites may in some cases extend into the Trias, as, for example, in Tongking, where Prof. E. Patte found rhyolitic tuffs containing *Myophoria*. Outside certain parts of Eastern Tongking, the southern districts of the Upper Laos and the Lower Laos, where they are typically marine, the Permian strata of Indo-China, partake rather of these characters, though marine intercalations with brachiopods occasionally occur in the sandy-argillaceous sequences.[1]

It is not possible in the existing state of knowledge to synchronise exactly the more intimate changes of land and sea in the southern Chinese basin proper with those of Indo-China, and still less with those of the Shan States and Tenasserim, where large areas are still unmapped and further comparative palæontological studies have still to be undertaken. But in the case of Yunnan and Indo-China there are broad features common to both which can only be interpreted as the results of the operation of identical causes. Apart from the close relationships of the marine faunas, with the possible exception of those of the Lower Yangsinian, there is correspondence in the ages of the volcanic rocks, between the lithological characters of the deposits themselves, between the physical conditions under

[1] *Bull. Serv. géol. Indo-Chine*, Vol. XIX, Fasc. 2, pp. 22-34, (1931).

which they were laid down, and, particularly, in the common occurrence of the *Gigantopteris nicotinæfolia* flora in both regions.

We have already seen that various parts of South China remained as islands above the surface of the Yangsinian sea and that such conditions became accentuated further to the west in Lopingian times. In the case of Indo-China we find independent evidence of a similar character, close enough to be impressive. M. Fromaget has proved that rocks of the neritic and continental types with their related lava flows, and in extreme cases the latter alone, may take the place of the Uralo-Permian limestones. He believes, moreover, that they were deposited in shallow lagoons, or around the shores of islands of varying sizes which existed outside the main geosynclinal channels, from the Middle Uralian to the end of Permian times, both as stages for the successive displays of volcanic activity which characterise the whole region and as the grounds on which flourished a flora whose affinities are with northern regions only.[1] *Gigantopteris nicotinæfolia* occurs in coal seams associated with sandstones, shales and tuffs of Lower or Middle Permian age in the Nam On valley, a tributary of the Mekong, to the north of Luang Prabang in the Upper Laos.[2] This is the most westerly occurrence of the flora yet discovered and it is within 150 miles of the Southern Shan frontier. (See Pl. 29).

It may be recalled here that the Lopingian limestones of the Southern Shan States betray their shallow water formation. They are clastic rocks, interbedded with shales containing varying quantities of calcareous matter, the products of the erosion of older rocks rather than true limestones of zoogenetic origin.

From at least Middle Permian times onwards (using the term in the sense adopted by Grabau), there is therefore much support for de Launay's ideas, adopted and quoted by M. M. Blondel and Fromaget, that the Shan-Yunnan-Indo-Chinese region then formed an archipelago of islands, girdled by coral reefs and often possessing active volcanoes, somewhat on the lines of existing conditions in the Malay Archipelago today. These islands laid off the southern and western coasts of Cathaysia, which at any rate for part of the period concerned, formed a portion of the "Continent Eurasiatique" of the French writers.[3]

[1] *Bull. Soc. géol. France*, 5th Serie, Tome 4, pp. 125-126, 156-157, (1934).
[2] *Bull. Soc. géol. France*, 5th Serie, Tome 4, pp. 140-142, (1934).
[3] *Bull. Serv. géol. Indo-Chine*, Vol. XIX, Fasc. 2, p. 42, (1931).

I have considered it necessary to outline these palæogeographical features from Yangsinian times onwards because in the terrestrial volcanic rocks of Yunnan and in the continental facies of the Lopingian of Eastern Yunnan and Western Kueichow, there is to be found the beginning of the final tendency to uplift and emergence which, accentuated in Red Bed and later times, resulted in the final disappearance of the sea and the freeing of the whole of South-Western China from marine deposition towards the close of the Trias, with the exception of a brief and limited incursion of the Shan Jurassic gulf into the extreme west of Yunnan. The term "final tendency to uplift", is chosen advisedly, for similar events had occurred in earlier geological epochs across the same terrain, in the Lower Devonian and Middle Carboniferous, for example, though not on so grand a scale nor continued to so definite a conclusion.

The Middle Permian and the Final Tendency to Uplift.

The formation of the salt-bearing Red Beds of Yunnan and Szechuan marked another stage in the orderly procession of these events. The basaltic regions of Central Yunnan and adjoining parts of Szechuan, another great island in the Lopingian sea, were subjected to severe and prolonged erosion, the products of which doubtless helped to build the clastic sediments of the near-by *Gigantopteris* coal measures and of the shallow straits further east still. There, above the limestones with *Lyttonia* and *Oldhamia*, are red shales, sandstones and further thin limestones, part of which are now known to belong to the uppermost Permian, but the bulk of which are of Lower Triassic age. In some parts of Central Yunnan long continued denudation removed the whole thickness of the volcanic rocks as well as the underlying Permian and Carboniferous strata, so that the basal conglomerates of the Red Beds may rest on any horizon from that of the igneous rocks downwards. The lower, saliferous Red Beds which follow them are the results of deposition and precipitation in an enclosed basin, the dessicated remains of an inland sea which became isolated from its oceanic connections to the south-east. Whether the sea in question was originally part of the Yehlangian or Upper Permian transgression as visualized by Grabau and Ting, or, whether it is more correctly regarded, as Hirth has postulated, as a connection of an early Triassic inundation, is a question which, in my opinion, is still an open one. Be this as it may, later events in Central Yunnan belong to lacustrine

Events associated with the Formation of the Red Beds.

and continental regimes culminating in the Norian-Rhætic coal measures. In Szechuan the Trias is followed by coal-bearing beds of Rhætic-Lower Jurassic age, but there the sinking of the interior of the basin led to the birth of the great Wealden lakes and the Lower Cretaceous fresh water Red Beds. The possibility of part of these being of Jurassic age must not, however, be overlooked.

Should the second of the two views eventually prove correct then the unconformity at the base of the Red Beds will represent a great physical hiatus between the Palæozoic and Mesozoic eras, while in late Triassic time, the area formed a land to the east and west of which laid the two marine gulfs of Amichou-Kueichow and Yunnan-i, respectively, to the description of which it is hoped to return in a later paper of this series.

Saurin studied the petrological characters of the Red Beds themselves and concluded that their elements were derived from the slow erosion in place of a granitic and metamorphic region, and such strata are occasionally, though by no means always, seen to form the floor below them.[1]

Red Beds of Triassic age have been found to occur in Szechuan, Indo-China and Siam. With the Red Beds of the Shan States those of Yunnan have nothing in common, beyond certain superficial lithological resemblances, with the proviso that it is safe to assume a Jurassic age for the whole of the Namyau Series on the strength of the fossils from the limestone bands, an assumption which I find it difficult to accept.

Conclusion.

La Touche pointed out long ago that the continental conditions prevalent in China did not reach the Shan States until the Jurassic period, but they were not, whatever age range they may possess, spread over the "whole eastern border of Gondwanaland", as he thought.[2] It is now apparent that the whole sequence of lagunary and lacustrine, continental and sub-continental deposits, generally of red bed types, which may be of any age from the Moscovian to the Lower Cretaceous and occur from the coast of Southern Burma eastwards through Siam and the Shan States, Indo-China, Yunnan, Szechuan and beyond, can no longer be regarded as coming within the territory of Gondwanaland or be classified in any way as "Gondwanas". They are to be associated rather with the northern

[1] *Bull. Soc. géol. France*, 5th Sér., Tome 3, p. 456, (1933).
[2] *Mem. Geol. Surv. Ind.*, Vol. XXXIX, Pt. 2, p. 355, (1913).

continental element, or with one or other of the sub-continents into which it had divided before early Mesozoic times.

The future detailed study of these rocks, particularly in the Shan States and Yunnan, cannot fail to yield results of the greatest importance in the elucidation of the many unsolved problems of this border-land "where two impinging continental margins have extended themselves alternately over an intervening and fluctuating sea during the interplay of Laurasia and Gondwana in the Mesozoic era".[1]

V. ACKNOWLEDGMENTS AND NOTE ON THE MAPS.

Every student of Chinese geology is under an obligation to the geologists of the Geological Survey of China and to those others whose writings, with theirs, illuminate the publications of the Geological Society of China. The preparation of this contribution to the geology of Yunnan would have been impossible without the use of the works of the authors listed in the bibliography which follows, and especially to those of the late Drs. V. K. Ting and Y. T. Chao and of A. W. Grabau, T. K. Huang, C. Y. Lee and Y. L. Wang. In addition to this, I have received courteous assistance in connection with particular problems, from the following authorities during the preparation of this paper, and to each of them my thanks are here formally expressed:—Prof. G. B. Barbour, Cincinnati; Prof. Wilhelm Credner, Munich; Prof. T. G. Halle, Stockholm; Prof. Arnold Heim, Zurich; Dr. Karl Krejci-Graf, Berlin; Prof. Etienne Patte, Poitiers; Dr. F. R. Cowper Reed, Cambridge and Dr. Eberhard Wirth, Celle in Hanover.

Notes on the Maps.

The geological sketch map (Pl. 30) is based entirely on traverses and can only be taken to illustrate the broad outlines of the chief formations in a very diagrammatic manner. It is a result of my own field work with the exception of:—

(a) the portion north and north-west of a line through Yunlung Chou, Tengch'uan Chou and Chingchiangkai which is added from the observations of Gregory and Credner. As they do not agree on the ages of the strata exposed between Lanping and Chiench'uan Chou, this section is particularly doubtful.

[1] A. L. Du Toit, p. 296.

(*b*) the portion between Paiyenching and Makai, which is taken from Credner's traverse.

(*c*) some of the occurrences of Upper Red Beds between Houching and Lufêng Hsien, which are added from the results of Credner's and Saurin's observations.

The group described as "Devonian to Permian", consists mainly of Permian limestones and basic rocks to the east of Tali Fu; elsewhere it includes Gregory's Minchia Series of Devonian age. The "Transition Systems" belong chiefly to the Pre-Palæozoic Kaoliang slates and phyllites, but in the east may include Cambrian rocks. The "Archæan" comprises the gneisses, schists and crystalline limestones of the T'sang Shan complex, west of Tali Fu. The topography of this map is taken from that of General H. R. Davies, published by the War Office in 1906.

On the smaller map (Pl. 29), the outline of the Red Basin of Szechuan is reduced from that published by C. Y. Lee on a scale of 1: 14,000,000 in 1934, and it includes not only the Cretaceous rocks of the centre, but also the Triassic and Jurassic formations of its outer rim.

The line indicating the approximate western limit of the *Gigantopteris* flora, as it is known to-day, is drawn to include the occurrences of this flora which have been described from Szechuan, Yunnan and the Upper and Middle Laos. It is interesting to note that its prolongation in the same direction to the south would include the known occurrence of this flora in South Eastern Sumatra.

It has been found impossible to mark the position of every locality mentioned in the paper on the maps, owing to their small scale, but in the few cases where this has not been done sufficient indication of their position has been added in the text.

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EXPLANATION OF PLATES.

PLATE 29.—Yunnan and Surrounding Regions.

,, 30.—Geological Sketch Map of part of Yunnan.

EARTHQUAKE SHOCKS AT PALIYAD IN KATHIAWAR. BY H. CROOKSHANK, B.A., B.A.I., D.Sc. (DUB.), *Superintending Geologist, Geological Survey of India.*

PART I.—THE EARTHQUAKES AND THEIR CAUSES.

A series of earthquake shocks has recently been experienced near Paliyad (22° 15′ : 71° 33′) in Kathiawar. The shocks began on the 26th June 1938, and were still continuing on the 15th August, 1938 the last day for which earthquake reports have been received. The shocks varied greatly in intensity, but were on the whole light. The heaviest occurred on the 12th July about 3·45 P.M., on the 20th July about 4·20 A.M., and on the 23rd July about 5·35 P.M. As will be seen from the table below, the earthquake activity seems to have reached its maximum on the 23rd of July, and to have thereafter decreased.

Introductory.

No. of shocks.		
Light.	Heavy.	Dates.
1	..	Before the 1st July.
21	..	1st to 8th July (8 days).
29	1	9th to 15th July (7 days).
39	1	16th to 22nd July (7 days).
46	1	23rd July (1 day).
20	..	24th to 30th July (7 days).
21	..	31st July to 6th August (7 days)
19	..	7th to 15th August (9 days).
196	3	

A complete list is given on pp. 592-595.

So far as I could ascertain, the earthquake damage up to the 23rd July was confined to the collapse of a weak mud wall in Paliyad on the 12th, and to minor cracks and falls of plaster on the 20th. About 5·35 P.M. on the 23rd, however, a severe shock did much damage in Paliyad (see p. 590). This was felt by most people as far away as Viramgam, Bhavnagar, Morvi and Rajkot, that is over an area of at least 4,000 square miles.

The maximum intensity of the shock of the 23rd July was confined to a very limited area around the town of Paliyad. Judging from the damage to buildings there the intensity of the shock must have just reached VII on the Mercalli scale. I append a map showing isoseismals VII, VI and IV on this scale. The isoseismals are very approximate, as it was not possible to get accurate information in the short time (4 days) spent by me in Kathiawar. Their general shape calls for no comment.

Intensity of shock of 23rd July.

The times at which the various shocks are supposed to have taken place have been given in my list whenever they were available. Unfortunately there are many discrepancies. Thus the earthquake of the 23rd is reported from one source as 5·30 P.M., from another less than 25 miles distant as 5·35 P.M., and from a third about 90 miles distant as 5·45 P.M. As the slow surface waves of an earthquake travel 2 to 3 miles a second these differences are inexplicable unless some of the times given are wrong.

Timing of shocks.

Without reliable information of the times at which an earthquake is felt in different areas it is impossible to calculate the rate of travel of the shocks, and I have not attempted to do so.

Opinions differed as to the direction from which the shocks in Paliyad came, but most people considered that they had come from the south. The cracks on the walls threw no light on this point. Horizontal cracks were the commonest. Cracks parallel to one or both diagonals of a wall were frequent. Vertical cracks were rare, but there must have been a considerable vertical component to the shocks to have split the capitals of the pillars holding up the dome of the temple. On the whole the directions taken by the cracks in the walls followed the lines of greatest weakness in the buildings, and gave little indication of the direction of the shocks.

Direction of shocks.

Although the intensity of most of the shocks at Paliyad was small, almost all of them were preceded by loud rumbling noises. Many noises were also recorded unaccompanied by any perceptible shocks. Many earthquakes are attended by similar sounds, but the general insistence on their loudness in the region all round Paliyad makes me think that they must have been an exceptional feature of the earthquakes here.

Noises.

Rock is present in this part of Kathiawar everywhere within a few inches of the surface. It consists of a vast horizontally bedded sheet of basalt, Deccan trap (see p. 582). Without an extensive and careful geological survey it would be impossible to make an accurate estimate of its thickness, but it is probably between one and four hundred feet. Such a relatively thin sheet of hard rock might well vibrate like a drum under the impact of quite a small earthquake. Whether this is the real explanation of the exceptionally marked rumblings it is impossible to say without more and better evidence.

Depth of focus of shocks.

No determination of the depth of focus of an earthquake is possible unless there are a considerable number of seismographs in the region of the earthquake which can give accurate times of arrival for the various waves (Heck, p. 104). The only seismograph, so far as I know, which picked up this earthquake, is the one at Colaba in Bombay (*Statesman*, 25th July 1938). One observation is of no use in fixing the depth of focus. The very local destruction caused by the earthquake suggests a shallow focus, but this in any case must be several miles below the surface. In the case of a similar swarm of earthquakes at Ito in Japan the depth of focus was about $3\frac{3}{4}$ miles below the surface of the ground (Davison, p. 248).

Panic caused by shocks.

Few, if any, of the inhabitants of Paliyad and the surrounding villages had ever felt an earthquake, so they were naturally terrified by the loud noises and tremors. All sorts of wild rumours were current. The most generally believed were stories to the effect that a huge cavity had opened in the earth under Paliyad, and that the noises and tremors were due to its roof collapsing. They were very much afraid that this cavity would ultimately reach the surface and swallow up Paliyad and its surroundings. There was also great apprehension of a flood which would destroy any villages in the neighbourhood, which had not already been swallowed up. The local shopkeepers were even more terrified than the cultivators, but their fears were characteristically lined with silver. They thought the tremors a sign of coal or oil beneath Paliyad.

The panic due to the weird earthquake noises and tremors was considerably increased by these wild rumours, so that by the 14th of July all those who could afford to leave the village had gone. The cultivators, however, stayed to tend their herds and crops,

and with them the *thandar*, the police and the doctor. All those who remained were living under improvised tents on high ground in case of floods.

On the 26th July, as the result of the severe shock of the 23rd, I was deputed to investigate the cause of these earthquakes, and, if possible, to reassure the local people. I left Calcutta that evening, and arrived in Paliyad on the 29th. I remained in that neighbourhood till the 31st, but unfortunately neither heard nor felt any tremors.

Geology of Paliyad area.

Paliyad lies in an undulating plain extending for many miles in all directions. The plain is varied here and there by hillocks rising 50 feet or so above the surrounding country. The present land surface corresponds very closely to the top of a single basalt flow of Deccan trap age. The hillocks are the remains of higher flows now almost completely worn away by erosion.

Thin red siliceous beds occur on the surface of the main flow over a wide area surrounding Paliyad. These are almost certainly the remains of a sedimentary bed deposited in the interval between successive basalt flows.

The main basalt flow is of rather an unusual type, as it contains numerous large olivine crystals easily visible to the naked eye. Such flows are unknown in typical Deccan trap country. The occurrence of such an unusual type of flow over a wide area, with its surface everywhere about the same height above sea-level, indicates that there is no important faulting. This indication is strongly supported by the presence in so many places of the above-mentioned red bed at a slightly higher level. The only sign of faulting that I could see was the presence of a few dykes just west of Nana Paliyad. Dykes such as these occasionally occur along faults, but in this case there was no indication that this was so. If they do represent faults they must be small ones, because the same unusual olivine-basalt flow is seen on either side of them.

I conclude that there are no strong faults in the vicinity of Paliyad. The earthquakes are, therefore, not likely to be due to the slipping of any faults exposed at the surface there.

The suggestion that the Kathiawar earthquakes were due to the presence of an oil-field is unfortunately an unlikely one. The basalt flows at Paliyad are older than any of the oil-bearing rocks

in India. It is most unlikely, therefore, that they conceal beds containing oil.

The seam of coal said to occur near Paliyad turned out to be a flow of obsidian (volcanic glass). This is an interesting occurrence, but can have no possible connection with the present series of earthquakes.

No obvious local reason for Paliyad earthquakes.

Thus there is, so far as I could ascertain from surface indications, no local reason why the earthquakes should have been more severe at Paliyad than elsewhere. It is a remarkable fact, however, that in the only available record (Oldham, 1926) of an earthquake of destructive violence in Kathiawar 'Rampoor near Pullgarde' was badly damaged. This is believed to refer to Rampur, 12 miles from Paliyad. The fact that the only two earthquakes recorded from Kathiawar have both been felt in the vicinity of Paliyad suggests that there is some subterranean feature favourable to the development of earthquakes in this area.

Recent geological history of Kathiawar.

The recent geological history of Kathiawar (Fedden, pp. 53-59) indicates that there has been a general uplift of the land amounting to 1,200 feet in places. The evidence on which this statement is based is the presence of miliolite (Porbandar stone), a sub-recent marine deposit, on the top of Chotila hill 1,173 feet above sea-level, and the common occurrence of raised beaches, oyster beds, and coral reefs far above the present high-water mark.

Stress of earth's crust in Kathiawar.

Where surface changes of this magnitude are taking place, the earth's crust must be in a severe state of strain. If the stress increases till it exceeds the rigidity of the earth's crust distortion takes place. This is usually accompanied by earthquakes. These may be violent or mild according as the crust is distorted suddenly or gives gradually. Stress in the earth's crust due to the relatively rapid uplift of the Kathiawar peninsula is almost certainly the ultimate cause of the present series of earthquakes.

Earthquake history of Kathiawar.

The past earthquake history of Kathiawar, so far as it is known, suggests that the uplift of the land there has not been associated with any great earthquake activity. In fact, if de Montessus de Ballore's map of Indian earthquakes (1904, Pl. 1) can be relied on,

this series of earthquakes is the first whose epicentral area is known to lie inside Kathiawar.

As great earthquakes are almost entirely confined to well-known earthquake zones, and as Kathiawar is certainly not one of these, there seems little likelihood that the present state of instability will culminate in a major earthquake. It is far more likely that the shocks will fade away gradually as the stress in the earth's crust is relieved. This is the normal course of events where swarms of earthquakes like the present ones are felt (Heck, p. 46).

The chief danger from earthquakes in Kathiawar is due to its propinquity to the Indus delta. This is a well-known earthquake area from which two disastrous shocks have been recorded in historical times (Oldham, T., pp. 6, 13 and 14). The more recent of these, in 1819, had its epicentre north of Cutch. Though this is 100 miles from Paliyad it caused the destruction of many buildings between that town and Ahmedabad, and also wrecked the alluvial tracts along the north and west coasts of Kathiawar.

The danger to Kathiawar from major earthquakes in the Indus delta should not be exaggerated. In the first place such great earthquakes have only occurred at very long intervals in the past. Thus there has only been one in the Indus delta since 1800 compared with 15 in the last 90 years in Baluchistan (West, Pl. 24). Then the intensity of an earthquake in Kathiawar with its epicentre in the Indus delta would be much less than at its source, though it could still be extremely destructive, as was proved by the earthquake of 1819. Finally, very severe damage in Kathiawar would probably be confined to the margins of that country where alluvial plains and unconsolidated rocks are common. Central Kathiawar is a great basalt shield with solid rock exposed everywhere a few inches below the surface. If the results of many great earthquakes are analysed it is found that destruction on massive tough rocks like basalts is much less than that on alluvium or badly consolidated rocks. This almost universal experience was borne out in the case of the great earthquake of 1819 when central Kathiawar escaped the wholesale destruction experienced in the alluvial regions of the north and west coast. (Oldham, 1926, pp. 40-42).

The history of Kathiawar shows that a great earthquake with epicentre there is most unlikely. It is, however, possible. If it came, it would destroy buildings over a very wide area; nor is there any way in which one can predict what that area would be.

The present earthquake swarm is no indication. Such earthquake swarms are seldom followed by great earthquakes. When they are, the epicentre of the main earthquake rarely coincides with that of the swarm (Davison, 1936, 246-264). It is, therefore, obviously useless to move away a few miles thinking that safety will be so obtained. For this reason I did my best to discourage those who wished to run away from Paliyad. I advised them to live in tents away from walls of houses till the earthquake shocks should abate and then to return to Paliyad and rebuild or repair the damaged buildings.

PART II.—EARTHQUAKE DAMAGE AT PALIYAD.

The damage done by the earthquakes in Kathiawar up to the time I left on the 1st of August was confined to the town of Paliyad. Here most of the *pukka* buildings have been cracked, but none have fallen. The *kutcha* buildings are also cracked, especially at the corners, and a few have fallen.

I am not competent to assess the damage done, but probably it lies somewhere between the figures of Rs. 30,000 and Rs. 3,00,000; the former figure if cracked buildings can be repaired without demolition, the latter if they have to be pulled down. Now each damaged building presents its own engineering problem, and really requires to be examined by an engineer with experience of repair of earthquake damage in other parts of India.

The Chief Engineer, Roads and Buildings, P. W. D., Bengal, has very kindly supplied me with the following notes from P. W. D. practice in Bengal.

Note on repairing earthquake shocks.

"Earthquake cracks are treated much like cracks from settlement or any other cause. If walls are not out of the plumb the cracks are opened out well, and then grouted with a mixture of 2 parts of sand to 1 of cement. Where the crack is at all wide it is good practice to push small pieces of fresh rock into the cement concrete filling the crack. In bad cracks 'tell-tales' of cement are usually inserted so that any further movement of the crack can be observed. Steel tie-rods can also be used in cases where this is considered necessary. The usual practice is to clear a hole on either side of the crack for the tie-beam. The space around the steel tie-rod is then filled in with concrete. Walls well grouted or tied together

in this manner are considered to be as strong as they were before the earthquake damaged them.

Masonry walls which are out of the plumb should generally be dismantled."

New buildings.

It is the practice in parts of the earth specially liable to earthquakes to build the larger structures with braced steel frameworks, or of reinforced concrete, and the smaller buildings of light and elastic materials such as bamboo and thatch. Details of such earthquake-proof structures can be obtained in a chapter on the design of earthquake-resisting buildings (Freeman, pp. 795-820). References to the best literature on this subject are given in the same book (pp. 709-724). Construction of this kind would be expensive in parts of Kathiawar at a distance from the ports, as none of the necessary materials would be readily available, nor could the expense be generally justified. I have shown (p. 584) that the danger from earthquakes in Kathiawar is only a small fraction of the danger in Baluchistan, and yet few buildings in that country outside Quetta have been specially designed to withstand earthquakes.

While rejecting as impracticable any building policy aiming at making Kathiawar earthquake-proof, I strongly favour such modifications of the present building methods as will tend to reduce damage from earthquakes.

Existing building practice in Kathiawar.

In the part of Kathiawar visited by me the *pucca* buildings are made either of random rubble or ashlar, the former being the commoner.

The stone used for the rubble is usually a heavy black basalt, that for the ashlar may be one or other of the sandstones so common in northern Kathiawar, or it may be a limestone known locally as Porbandar stone. Lime mortar is used in most cases, but cement is seen to some extent along the railway lines. The foundations of *pucca* buildings in all central Kathiawar are on solid rock.

Heavy masonry walls such as those described are more vulnerable to earthquakes than other forms of building construction, but they are cheap and cool and stand a long while. I do not consider it necessary or desirable to replace them by earthquake-proof structures, but more care should be taken in building new houses to see that the mortar used is the best available, and that the stones are

set with a good bond. The cracks in Paliyad were in most cases worst where least attention had been paid to bond. The few *pucca* walls which had fallen had all been built with mortar so poor that it could be crumbled between one's finger and thumb. To use such poor stuff in a country like Kathiawar, where excellent lime is readily available, is almost criminal.

Design of Buildings.

As regards the general design of buildings the following remarks in Messrs. Auden and Ghosh's report on the 1934 earthquake in Bihar are equally applicable to Kathiawar.

"Buildings should be of simple design, the parts so well-tied and the whole structure so rigid that it would react as one unit to earthquake waves. The several parts of irregular buildings do not synchronise during a shock, and severe stresses are set up between the individual units. These remarks apply especially to high structures, *e.g.*, a church steeple erected on a tower is frequently destroyed from the base of the steeple; the tower and steeple each having a different vibration period and opposing directions of movement, with the result that the acceleration can be doubled."

"Buildings should be kept as low as is conveniently possible compared with their lateral dimensions. The object should be to keep the amplitude of vibration as low as possible at the highest part of the structure, and so reduce acceleration, for any particular period of vibration."

"Buildings of irregular shapes, with wings, protruding verandahs, porches, etc., have invariably suffered. The same applies to buildings to which additions have been made by the abutting of new walls directly, on earlier ones, without dovetailing. The whole building should form one unit. Verandahs and porches should not consist of a series of independent pillars with a roof resting on top, but should be integral parts of the building."

"Excrescences such as towers, turrets, pinnacles, etc., are dangerous both to human beings and to buildings, and should be avoided. Flimsy parapets, balustrades, and similar structures have caused death to many."

"Windows are a source of weakness to buildings, and a more careful and better spacing should be attempted. Windows should

be kept away from outer corners of buildings as far as possible. Wide window areas should be compensated by stronger intervening walls."

"The use of timber-frames in *kutcha-pucca* and *kutcha* buildings should be encouraged. Buildings consisting of a platform or sole-plate supporting timber verticals that are well-tied by cross and diagonal beams and firmly attached to the roof are preferable. The weight of the roof would thus be shared both by the walls and the pillars and the tendency of the walls of such a building would be to move together as a unit. Timber pillars are greatly to be preferred to brick pillars."

There are some very old houses in Paliyad made of masonry with a wooden framework. These were not damaged at all by the recent earthquake. I have no doubt that an extension of this form of building in Kathiawar would be a valuable insurance against earthquakes, but it is doubtful whether suitable timber for this purpose could be obtained now-a-days at a reasonable cost.

The remarks above about buildings being kept low compared to their lateral dimensions are particularly applicable in Paliyad. Many of the shopkeepers' houses are high and narrow. The upper storeys have in most cases been badly cracked. The mortuary attached to the hospital is a particularly good example. There is only a single very small room, but it is about 15 feet high and has a heavy roof. Under the impact of the earthquake it must have vibrated very severely, with the result that it has been badly cracked, though it is a new and comparatively well-built building.

According to the Chief Engineer, Roads and Buildings, Bengal, it is good practice in earthquake areas to put in a ring of cement concrete six inches thick and the full width of the wall just above the level of the lintel all round a house. This costs little, is valuable in stopping cracks, and generally strengthens the building at its weakest point. Where there is more than one storey a ring is needed for each storey.

Roofing.

Lightness is the object to be aimed at in roofing. The Mangalore and country tiles now used for the purpose are rather heavy. In a severe earthquake they might crash down as one piece, burying everything under them. The large sheets of asbestos now sold for roofing would be much lighter and less destructive if they fell. They are said to be little dearer than Mangalore tiles. If they could

gradually replace the tiles throughout Kathiawar it would greatly reduce the danger from earthquakes.

Mud Huts.

The homes of the cultivators have mud walls. Where these have been built on a good wide stone plinth, and with a suitable taper, they have not collapsed. Those walls that have fallen were damp, the moisture having risen and permeated them through a badly constructed and inadequate plinth. If these plinths had watertight lime fillings, it would be a great improvement.

It is the local practice to add straw, pieces of tile, or pottery, and small chips of stone to the mud walls. This practice is probably excellent, but in some of the mud walls which had fallen I saw quite large rounded boulders. These are undoubtedly a source of danger, and should be avoided in this form of building.

Nearly all the mud walls were cracked at the corners. Cracking of this sort would be greatly reduced if there is a timber framework such as has already been described (p. 588). It is doubtful, however, if this would be worth the expense.

Most of the mud huts have roofs made of half-round country tiles. These would certainly crash down and bury the inhabitants in a bad earthquake. I regard them as much more dangerous than the mud walls, which would probably collapse without doing much harm. Thatch or asbestos sheeting would be a great improvement. Unfortunately the former is not available in this part of Kathiawar and the latter is probably too expensive. The use of these materials for roofing should be encouraged as far as possible.

Width of streets.

A feature emphasised in the recent report on the Quetta earthquake (West, p. 224) is the loss of life due to the narrowness of the streets. This 'made it impossible for people who did have time to escape out of their houses to reach a place of safety'. West recommended that 'the width of the streets should be not less than the combined height of the houses on either side' (p. 235).

The streets in Paliyad and in most of the older towns in Kathiawar are narrow. Every opportunity should be taken to increase their width. The coastal towns in Kathiawar, especially those in the

north and west, are probably the most vulnerable to earthquakes. If their streets are as narrow as those in other parts of Kathiawar, steps should be taken as soon as possible to widen them.

Several of the damaged buildings were specially shown to me for my opinion as to what could be done to them. These are as follows:—

The Thandar's office and quarters.
The hospital and mortuary.
Two temples.
A two-storied new building near the old temple belonging to a wealthy citizen.

Having discussed the matter with the Chief Engineer, Roads and Buildings, Bengal, I am of opinion that the central portion of the Thandar's office can be repaired, but that the ends will have to be dismantled and rebuilt.

The hospital and mortuary are badly cracked, but it should be possible to repair them without dismantling them.

The capitals of the pillars supporting the dome of a new temple built alongside the ancient one are badly cracked, but the shafts of the pillars and the dome itself seemed little damaged. It is suggested that the structure could be saved by fitting steel sleeves around the capitals to hold them together.

The other temple examined is much cracked, but only one of the cracks seems to be very serious. Due to this crack the whole of one high outer wall is now slightly out of the plumb. It is doubtful if this can be saved, but before it is dismantled expert engineering advice should be obtained, as much expense would be avoided if it could be pulled together.

The upper storey of the above-mentioned building belonging to a wealthy citizen of Paliyad is rather badly cracked, but I think that it could safely be repaired.

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List of shocks felt in the Recent Series of Earthquakes in Kathiawar.

Date.	Hours.	Place where felt.	No. of shocks.	Source of Information.	Remarks.
26th June	..	Paliyad	1	Thandar, Paliyad	Very slight.
4th July	..	Do.	3	Sub-medical Officer, Paliyad.	Accompanied by big noise as loud as a thunder storm.
5th July	6 to 7 A.M.	Do.	2	Thandar, Paliyad	No damage.
	Afternoon	Do.	2	Ditto	Do.
6th July	Daytime	Do.	1	Sub-medical Officer, Paliyad.	One big shock.
7th July	1-30 A.M.	Do.	1	Thandar, Paliyad	No damage.
	Day	Do.	a few	Sub-medical Officer, Paliyad.	
	Night	Do.	7	Ditto.	
8th July	After 3 P.M.	Do.	3	Thandar, Paliyad	No damage.
	10 P.M. to 12 midnight.	Do.	2	Ditto	Do.
9th July	7 to 7-30 A.M.	Do.	2	Ditto	Do.
	Afternoon and night.	Do.	6	Ditto	Do.
10th July	6-30 to 7 A.M.	Do.	2	Ditto	Do.
12th July	3-45 P.M.	Do.	1	P. A., E. Kathiawar Agency, Bhavnagar Observatory.	A kutcha wall fell. A strong earthquake shock felt at railway station within radius of 25 miles from Paliyad.
13th July	2-5 A.M.	Do.	1	Thandar, Paliyad	No damage.
	6 to 7-45 A.M.	Do.	4	Ditto	Do.
	10-30 A.M.	Do.	1	Ditto	Do.
	Before noon	Do.	3	Ditto	Do.
14th July	At night	Do.	4	Ditto	Mainly noise.
15th July	11 A.M. to 12 noon	Do.	1	Ditto	Do.
	At night	Do.	5	Ditto	No damage.
16th July	At night	Do.	2	Ditto	Mainly noise.
17th July	7-45 to 8 A.M.	Do.	2	Ditto	Do.
	10 P.M.	Do.	1	Ditto	Do.
18th July	8 P.M. to	Do.	12	Ditto	No damage.
19th July	8 A.M.				
20th July	Night	Do.	3	Ditto	Mainly noise.

List of shocks felt in the Recent Series of Earthquakes in Kathiawar—contd.

Date.	Hours.	Place where felt.	No. of shocks.	Source of Information.	Remarks.
20th July	4-20 A.M.	Paliyad	1	Thandar, Paliyad	This shock was severe in Paliyad, lasted about 5 seconds and was followed by other small jerks. It was also felt in the surrounding villages of Paliyad Thana, and in Bhavnagar and Jasdan States. As the result of this shock almost all the *pucca* buildings in the village had tiny irregular cracks. *Kutcha* houses escaped damage. Some plaster fell.
	4-20 A.M.	Dhandhuka (22° 25′ : 72° 0′).	1	District Magistrate, Ahmedabad.	Shocks lasted from 3 to 25 seconds according to different observers. One observer stated that there were two shocks. Shocks were accompanied by unusual sounds like those of an aeroplane or motor car in motion. They shook observers' seats but did not throw down loose objects.
	4-30 A.M.	Babra Harsurpur.	1	P. A., W. Kathiawar Agency.	Mild shocks lasted 3 to 4 seconds. No damage.
	4-20 A.M.	Radius of 25 m. from Paliyad and at Bhavnagar.	..	Observatory, Bhavnagar	A loud detonation and strong shock. Very mild at Bhavnagar.
21st July	Before 9 A.M.	Paliyad	3	Thandar, Paliyad	Mainly noise.
	10-5 A.M.	Do.	1	Ditto	No damage.
	11-30 A.M.	Do.	1	Ditto	Do.
22nd July	After midnight 21st July 1938.	Do.	1	Ditto	Do.
	Early morning	Do.	2	Ditto	Do.
	Early morning	Do.	3	Ditto	Mainly noise.
	10-15 P.M.	Do.	1	Observatory, Bhavnagar.	
23rd July	2-35 A.M.	Do.	1	Ditto.	
	6-15 A.M.	Do.	1	Thandar, Paliyad	Mainly noise.
	6-25 A.M.	Do.	1	Ditto	Do.
	6-40 A.M.	Do.	1	Observatory, Bhavnagar	Heavy shock.
	7-25 A.M.	Do.	1	Ditto	Do.
	2-5 P.M.	Do.	1	Ditto	Do.
	5-30 P.M.	Do.	1	Thandar, Paliyad	The shock of 5-30 P.M. was the heaviest of the series. Two *pucca* walls and a corner of a *pucca* cow shed fell. All *pucca* buildings were badly cracked, but not a single one collapsed. About 40 *kutcha* houses were badly damaged.

List of shocks felt in the Recent Series of Earthquakes in Kathiawar—contd.

Date.	Hours.	Place where felt.	No. of shocks.	Source of Information.	Remarks.
23rd July .	Night of the 23rd	Paliyad . .	40	Thandar, Paliyad . .	Mainly noise.
	5-35 P.M. .	Within radius of 100 m. round Paliyad.	1	Observatory, Bhavnagar	Very severe at Paliyad when it damaged more than 100 houses.
	5-45 P.M. .	Borsad (22° 26′ ; 73° 0′).	5	Collector of Kaira . .	Lasted two seconds. Felt by persons sitting or lying.
		Limbdi . .	1	Resident, Kathiawar Agency.	Felt though not severely.
		Wadhwan .	1	Ditto . .	Do.
		Rajkot . .	1	Ditto . .	Do.
		Babra . .	1	Ditto . .	Do.
24th July .	Daytime .	Paliyad . .	3	Thandar, Paliyad . .	Mainly noise.
	At night .	Do. . .	3	Ditto . .	No damage.
25th July .	12-30 P.M. .	Do. . .	1	Ditto . .	Do.
26th July . to 27th July .	11-30 P.M. . to 10 A.M.	Do. . .	3	Ditto . .	Do.
27th July . to 28th July .	10-45 P.M. . to 10 A.M.	Do. . .	6	Ditto . .	Do.
29th July .	1 A.M. . .	Do. . .	1	Ditto . .	Do.
30th July .	0-30 A.M. .	Do. . .	1	Chief Medical Officer, Bhavnagar State Railway.	Do.
1st August .	11-30 A.M. .	Do. . .	1	Thandar, Paliyad . .	Mainly noise.
	10-45 P.M. .	Do. . .	1	Ditto . .	Do.
3rd August .	9-5 A.M. .	Do. . .	1	Ditto . .	Do.
	9-7 A.M. .	Do. . .	1	Ditto . .	Do.
	9-10 A.M. .	Do. . .	1	Ditto . .	Do.
	9-30 A.M. .	Do. . .	1	Ditto . .	Do.
	4-50 P.M. .	Do. . .	1	Ditto . .	Do.
	By day .	Paliyad Road .	4	Chief Medical officer, Bhavnagar State Railway.	Do.
	By night .	Do. . .	1	Ditto . .	Do.
	. .	Paliyad . .	9	Ditto . .	Do.
4th August .	0-45 A.M. .	Do. . .	1	Thandar, Paliyad . .	Do.
5th August .	3-15 P.M. .	Do. . .	2	Chief Medical Officer, Bhavnagar State Railway.	Heavy shocks.
	At night .	Do. . .	2	Ditto.	

List of shocks felt in the Recent Series of Earthquakes in Kathiawar—concld.

Date.	Hours.	Place where felt.	No. of shocks.	Source of Information.	Remarks.
5th August . 6th August .	9 A.M. to 9 A.M.	Paliyad . .	3	Thandar, Paliyad . .	Mainly noise.
6th August .	Night . .	Do. . .	2	Chief Medical Officer, Bhavnagar State Railway.	
6th August . 7th August .	9 A.M. . . to 9 A.M. .	Do.	2 / 1	Thandar, Paliyad .	Mainly noise. / No damage.
7th August .	7-55 A.M. .	Do. . .	1	Chief Medical Officer, Bhavnagar State Railway.	
	Day . .	Do. . .	3	Ditto.	
	Night . .	Do. . .	2	Ditto.	
7th August . 8th August .	9 A.M. . . to 9 A.M. . .	Do. .	3	Thandar, Paliyad . .	Mainly noise. No damage.
8th August .	Day . .	Do. . .	2	Chief Medical Officer, Bhavnagar State Railway.	
	Night . .	Do. . .	1	Ditto.	
9th August . 10th August .	9 A.M. . . to 9 A.M. . .	Do. .	1	Thandar, Paliyad . .	No damage.
10th August .	Night . .	Do. . .	1	Chief Medical Officer, Bhavnagar State Railway.	
10th August 11th August .	9 A.M. . . to 9 A.M. . .	Do. .	1 / 1	Thandar, Paliyad .	Mainly noise. / No damage.
11th August .	7-30 P.M. . to 9-30 A.M. .	Do. .	1	Chief Medical Officer, Bhavnagar State Railway.	Shocks were heavy. Roofs were shaken.
11th August . 12th August .	9 A.M. . . to 9 A.M. . .	Do. .	1	Thandar, Paliyad . .	No damage.
13th August . 14th August .	9 A.M. . . to 9 A.M. . .	Do. . .	1	Ditto . .	Do.
14th August .	Night . .	Do. . .	2	Chief Medical Officer, Bhavnagar State Railway.	Do.
15th August .	Night . .	Do. . .	1	Ditto.	

The Shocks felt in Paliyad after the 30th July must have been light as none of them were felt in Botad 9 miles to the south.

MISCELLANEOUS NOTE.

Quarterly Statistics of production of Coal, Gold and Petroleum, in India and Burma : July tc September, 1938.

Coal.

—	July.	August.	September.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	22,919	23,004	22,327	68,250
Baluchistan	1,035	1,329	1,159	3,523
Bengal	566,549	625,214	721,094	1,912,857
Bihar	1,142,709	1,234,708	1,474,627	3,852,044
Orissa	3,993	4,706	3,904	12,603
Central Provinces	114,746	126,357	133,441	374,544
Punjab	6,971	7,362	10,248	24,581
TOTAL	1,858,922	2,022,680	2,366,800	6,248,402

Gold.

—	July.	August.	September.	Quarterly total for each Company.
	Ozs.	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	8,639	8,654	8,391	25,684
The Champion Reef Gold Mines of India, Ltd.	5,982	5,991	5,775	17,748
The Ooregum Gold Mining Company of India, Ltd.	4,185	4,305	4,768	13,258
The Nundydroog Mines, Ltd.	8,369	8,430	8.104	24,903
TOTAL	27,175	27,380	27,038	81,593

Petroleum.

—	Crude petroleum.	Total gasolene from natural gas.*
	Gallons.	Gallons.
Assam	16,536,018	*Nil.*
Punjab	7,409,080	141,729
TOTAL .	23,945,098	141,729
Burma	67,046,661	2,473,032

* These figures represent the total amounts of gasolene derived from natural gas at the well-head. Of these amounts, a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries. The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous Records.

A. M. HERON.

INDEX TO RECORDS, VOLUME 73.

I

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RECORDS

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THE GEOLOGICAL SURVEY OF INDIA.

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CONTENTS.

PART 1.

PART 2.

PART 3.

PART 4.

LIST OF PLATES, VOLUME 73.

FIG. 2.—Pyrite (P) replaced by sphalerite (S), in turn veined by chalcopyrite (C) and galena (G). P. S. 278. × 54.
FIG. 3.—Veins of galena and bismuthinite (white) in wolfram. P. S. 267. × 54.
FIG. 4.—Ex-solution droplets of bismuth in bismuthinite. P. S. 277. Oil immersion. × 540.

Dipterocarpoxylon garænse, sp. nov., G. S. I. Type No. 16502.

PLATE 15.—FIG. 1.—Transverse section showing distribution of vessel, rays and vertical gum ducts. Note the arrangement of gum ducts at the right hand corner (Gd). × 10.
FIG. 2.—Transverse section showing distribution of small (Sv) and large vessels in comparison with that of gum ducts (Gd). × 40.
FIG. 3.—Transverse section showing parenchyma and tracheids round the vessels. Note also the distribution of metatracheal parenchyma cells. × 75.
FIG. 4.—Transverse section showing a pair of gum ducts surrounded by rows of parenchyma cells. × 35.
FIG. 5.—Tangential section showing distribution, width and height of rays. Note also the size and shape of the cells forming different types of rays. × 50.
FIG. 6.—Tangential section showing tyloses in the vessels. × 110.

Dipterocaropxylon garænse, sp. nov., G. S. I. Type No. 16502.

PLATE 16.—FIG. 1.—A vessel element showing inter-vessel pits. × 90.
FIG. 2.—Radial section showing inter-vessel pits (Ivp) and fungal hyphæ (H). × 440.
FIG. 3.—Radial section showing vessel-ray pits (Vrp). Note their distribution and size. × 440.

Dryoxylon sp., G. S. I. No. K40/485.

FIG. 4.—Transverse section showing general structure of the wood. × 10.
FIG. 5.—Tangential section showing size and distribution of rays. Note the shape of individual cells of rays. × 75.
FIG. 6.—Transverse section showing distribution and arrangement of wood fibres. × 35.

Inter-trappean Fish Remains.

PLATE 17.—FIG. 1.—A Pristolepid scale (K29/629). × 20.
FIG. 2.—A Nandid scale (K29/628). × 20.
FIG. 3.—A fragment of a Clupeoid scale (K32/159). × 15.
FIG. 4.—A Labyrinthid scale (K32/147) allied to *Polyacanthus* C. V. × 7.
FIG. 5.—An impression of a Serranid scale (K29/629). × 3.
FIG. 6.—A fragment of a Cyptinoid scale (K32/149). × 7.
FIG. 7.—A fragment of an Osteoglossid scale (K29/631). × 3.
FIG. 8.—Another fragment of an Osteoglossid scale (K29/631). × 3.

Inter-trappean Fish Remains.

Seismograms of the Baluchistan (Quetta) Earthquake of May 31, 1935.

MGIPC—M—VIII-1-17—15-8 39—800.

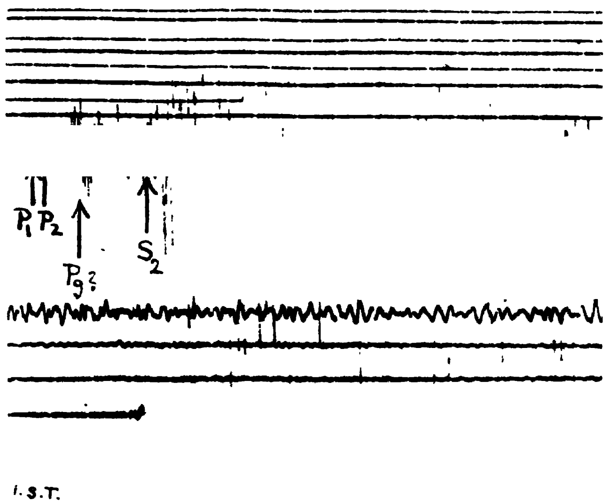


FIG. 1. N.-S. COMPONENT.

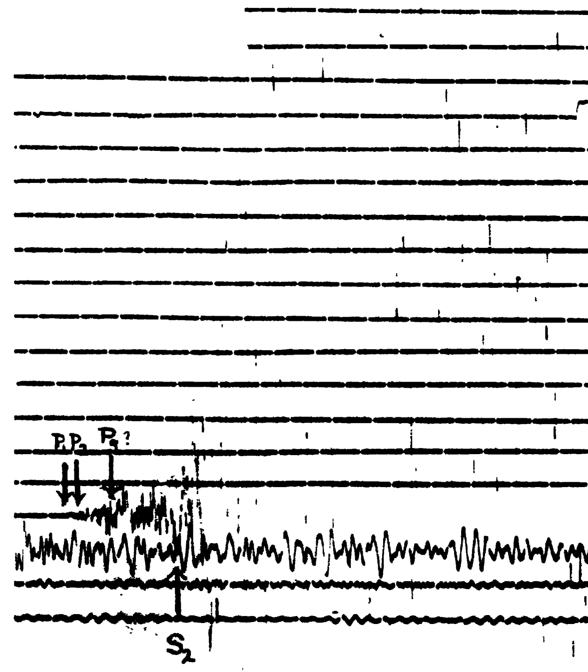
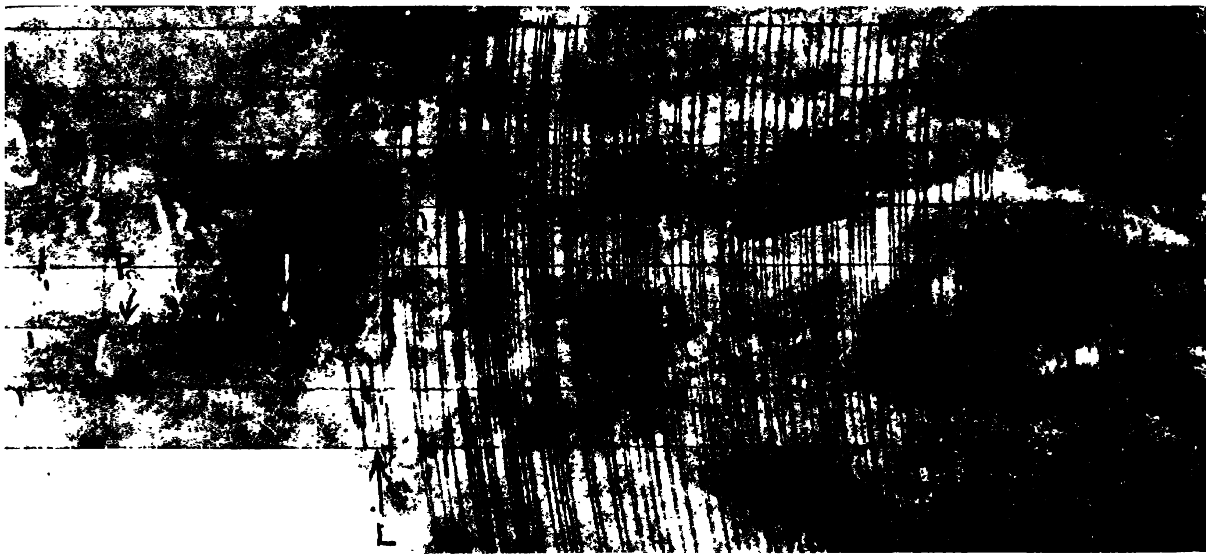


FIG. 2. E.-W. COMPONENT.

SEISMOGRAM OF THE BALUCHISTAN (QUETTA) EARTHQUAKE OF MAY 31, 1935.

BOMBAY (MILNE-SHAW).

Records, Vol. 73, Pl. 26.

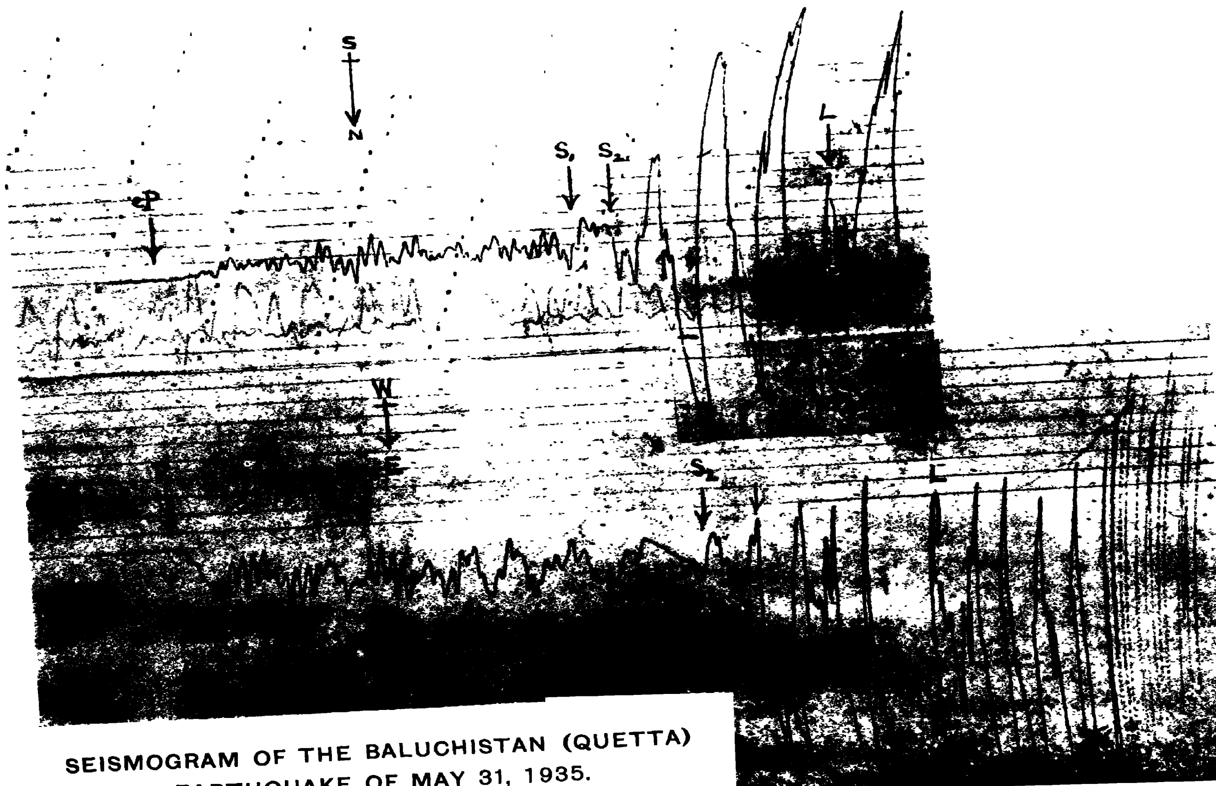


N.-S. COMPONENT.

SEISMOGRAM OF THE BALUCHISTAN (QUETTA) EARTHQUAKE OF MAY 31, 1935.

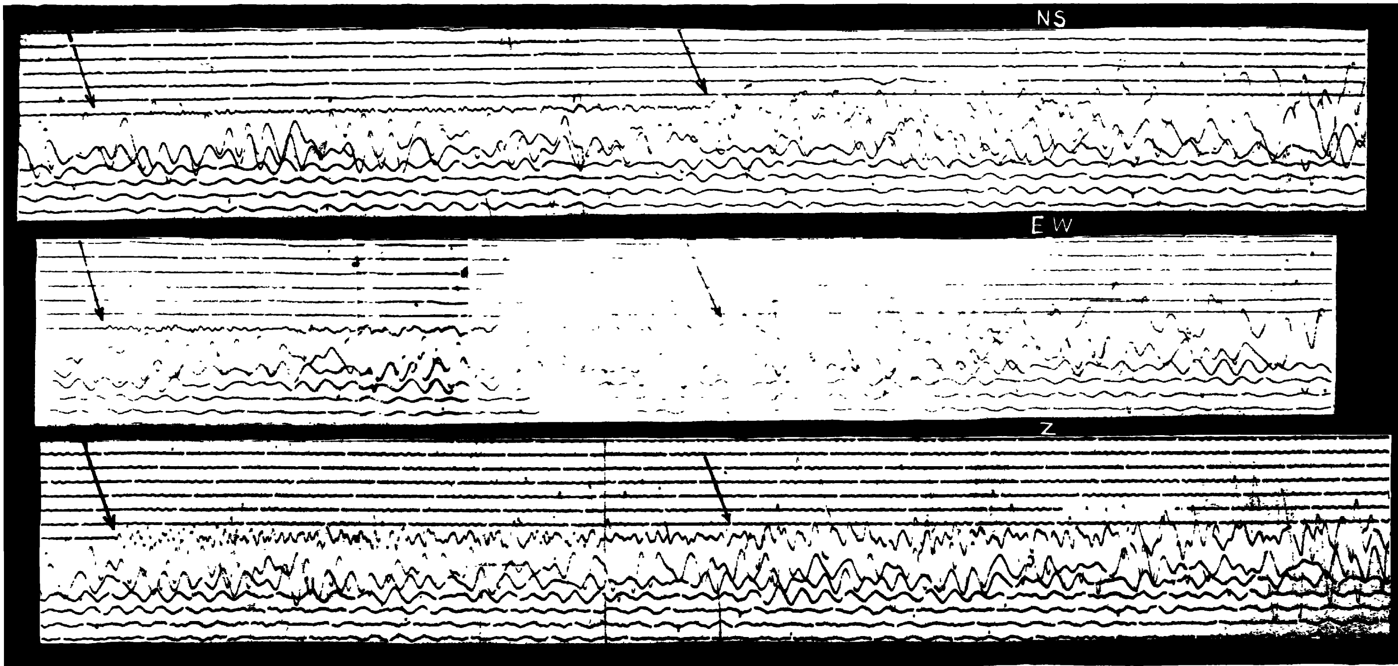
AGRA (OMORI).

G. S. I., Calcutta.



SEISMOGRAM OF THE BALUCHISTAN (QUETTA)
EARTHQUAKE OF MAY 31, 1935.

CALCUTTA (OMORI)

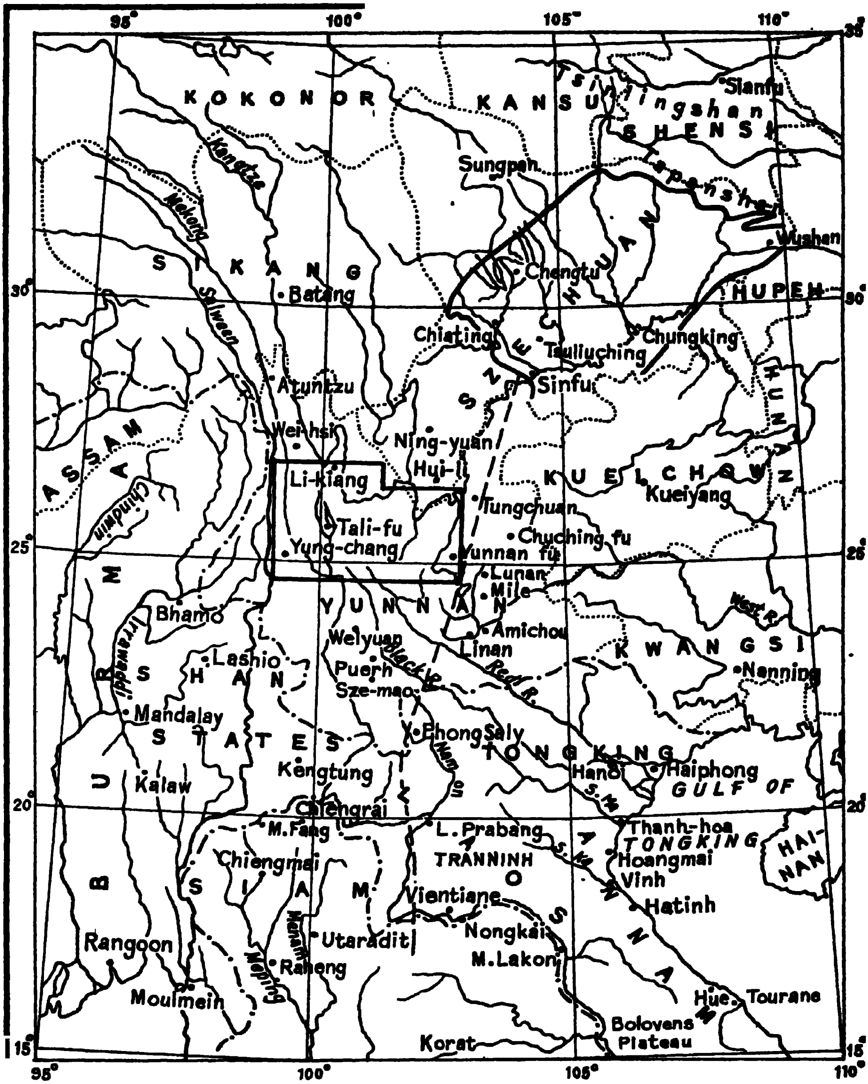


N.-S., E.-W. AND Z. COMPONENTS, KEW.

SEISMOGRAM OF THE BALUCHISTAN (QUETTA) EARTHQUAKE OF MAY 31, 1935.

G. S. I., Calcutta.

Records, Vol. 73, Pl. 29.



LINES (STRAIGHT) ENCLOSE AREA OF LARGER MAP. LINES (CURVED) ENCLOSE RED BASIN OF SZECHUAN. BROKEN LINE MARKS APPROXIMATELY KNOWN WESTERN LIMIT OF THE *GIGANTOPTERIS* FLORA.

YUNNAN AND SURROUNDING REGIONS

(Scale. 1 : 15,000,000)

or 236·7 miles to 1 inch.

G. S. I., Calcutta.

Vol. IX, 1876.

Part 1 (out of print).—Annual report for 1875. Geology of Sind.

Part 2 (out of print).—Retirement of Dr. Oldham. Age of some fossil floras of India. Cranium of Stegodon Ganesa, with notes on sub-genus and allied forms. Sub-Himalayan series in Jamu (Jummoo) Hills.

Part 3 (out of print).—Fossil floras in India. Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Maleri and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.

Part 4 (out of print).—Fossil floras in India. Osteology of Meryoopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

Vol. X, 1877.

Part 1 (out of print).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheira in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Embydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (out of print).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack, Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (out of print).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (out of print).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis', McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

Vol. XI, 1878

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (out of print).—Geology of Sind (second notice). Origin of Kumaon lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

Part 3 (out of print).—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1 (out of print).—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia. Siwalik beds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan). Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2 (out of print).—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3 (out of print).—Geological features of northern Madura, Padukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia speciosa, Royle (Sphenophyllum trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbudda.

Part 4.—"Attock Slates" and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1 (out of print).—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Noggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part .—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin Ferruginous beds associated with basaltic rocks of North-Eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab Appendix to ' Palæontological notes on lower trias of Himalayas '. Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain : and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danaite from Khetri mines, Rajputana ; with remarks on Jaipurite (Syepoorite). Zinc-ore (Smithsonite and Blende) with barytes in Karnul district, Madras. Mud-eruption in island of Cheduba.

Part 3 (out of print).— Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Unification of geological nomenclature and cartography. Geology of Arvali region, central and eastern Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah district, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district ; (2) arsenical pyrites in same neighbourhood ; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Gold-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kays (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosalpore, Jabalpur district. Umaria coal-field.

Part 3 (out of print).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussoorree. Cretaceous coal-measures at Borsora in Khasia Hills, near Laour in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1 (out of print).—Annual report for 1883. Smooth water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Kurnool district. Geology of Chuari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (out of print).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Rediscovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (out of print).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt range. Sites for boring in Raigarh Hingir coal field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishâpur, Khorassan. Fiery eruption from Minbyin mud volcano of Cheduba Island, Arakan. Langrin coal field, South-West Khasia Hills. Umaria coal field.

Part 4 (out of print).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

Vol. XVIII, 1885.

Part 1 (out of print).—Annual report for 1884. Country between Singareni coal field and Kistna river. Geological sketch of country between Singareni coal field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2 (out of print).—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (out of print).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthalla and Chandpur meteorites. Oil wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmein district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (out of print).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1 (out of print).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field notes. Section from Simla to Wangtu, and petrological character of Amphibolites and Quartz-Diorites of Sutlej valley.

Part 2 (out of print).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruptive rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-note from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt range, Punjab.

Part 2 (out of print).—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5— to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west, of Salt-range, in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Woolaston Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-fields, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part I.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicyonodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive-group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr Johannes Walther. Coal fields of Lairungao, Meosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1 (out of print).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-spring near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (out of print).—Mammalian Bones from Mongolia. Darjiling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1 (out of print).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dasht-i-Bedalot; with appendices on Chammans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Saféd Kóh. Jherria Coal-field.

Part 3 (out of print).—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (out of print).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Amber-like Resin in Burma. Triassic Deposits of Salt-range.

Vol. XXVI, 1893.

Part 1 (out of print).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma, Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2 (out of print).—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (out of print).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4 (out of print).—Geology of country between Chappar Rift and Harnai in Baluchistan. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

Vol. XXVII, 1894.

Part 1 (out of print).—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.

Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.

Part 3 (out of print).—Cambrian Formation of Eastern Salt-range. Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn. and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

Part 4 (out of print).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistan. Highly Phosphatic Mica Periodotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Periodotite in Bengal.

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.

Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.

Part 3 (out of print).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.

Part 4 (out of print).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyans. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

Vol. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.

Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwana-land". Notes.

Part 3 (out of print).—Igneous Rocks from the Tochi Valley. Notes.

Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

Vol. XXX, 1897.

Part 1 (out of print).—Annual report for 1896. Norite and associated Basic Dykes and Lava flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.

Part 2.—Cretaceous Deposits of Pondicherri. Notes.

Part 3 (out of print).—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikaner. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.
Part 4 (out of print).—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Caut. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

Vol. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjiling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.
Part 2 (out of print).—Lt.-Genl. C. A. MacMahon. Cyclobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.
Part 3 (out of print).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.
Part 4 (out of print).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

Vol. XXXII, 1905.

Part 1.—Review of Mineral Production of India during 1898-1903.
Part 2 (out of print).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and U in Tibet. Bauxite in India. Miscellaneous Notes.
Part 3 (out of print).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites-Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.
Part 4.—Obituary notices of H B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

Vol. XXXIII, 1906.

Part 1 (out of print).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.
Part 2 (out of print).—General report for 1905. Lashio Coal-field, Northern Shan States. Namma, Mansang and Man-se-le Coal-fields, Northern Shan States, Burma. Miscellaneous Notes.
Part 3 (out of print).—Petrology and Manganese-ore Deposits of Sausar Tahsil, Chhindwara district, Central Provinces. Geology of part of valley of Kanhan River in Nagpur and Chhindwara districts, Central Provinces. Manganite from Sandur Hills. Miscellaneous Notes.
Part 4 (out of print).- Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond-bearing Deposits. Index to Volume XXXIII.

Vol. XXXIV, 1906.

Part 1 (out of print).—Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan. Coal Occurrences in Foot-hills of Bhutan. Dandli Coal-field: Coal outcrops in Kotli Tahsil of Jammu State. Miscellaneous Notes.
Part 2 (out of print).—Mineral production of India during 1905. Nummulites Douvillei, with remarks on Zonal Distribution of Indian Nummulites. Auriferous Tracts in Southern India. Abandonment of Collieries at Warora, Central Provinces. Miscellaneous Notes.
Part 3 (out of print).—Explosion Craters in Lower Chindwin District, Burma. Lavas of Pavagad Hill. Gibbsite with Manganese-ore from Talevadi, Belgaum district, and Gibbsite from Bhekowli, Satara District. Classification of Tertiary System in Sind with reference to Zonal Distribution of Eocene Echinoidea.

Part 4 (out of print).—Jaipur and Nazira Coal-fields, Upper Assam. Makum Coal-fields between Tirap and Namdang Streams. Kobat Anticline, near Seiktein, Myingyan district, Upper Burma. Asymmetry of Yenangyat-Singu Anticline, Upper Burma. Northern part of Gwegyo Anticline, Myingyan District, Upper Burma. Breynia Multituberculata, from Nari of Baluchistan and Sind. Index to Volume XXXIV.

VOL. XXXV, 1907.

Part 1 (out of print).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokachi and neighbourhood, Dacca district.

Part 2 (out of print).—Indian Aerolites. Brine-wells at Bawgyo, Northern Shan States. Gold-bearing Deposits of Loi Twang, Shan States. Physa Prinsepii in Maestrichtian strata of Baluchistan. Miscellaneous Notes.

Part 3.—Preliminary survey of certain Glaciers in North-West Himalaya. A.—Notes on certain Glaciers in North-West Kashmir.

Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

VOL. XXXVI, 1907-08.

Part 1 (out of print).—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic outburst of Late Tertiary Age in South Hsenwi, N. Shan States. New suidæ from Bugti Hills, Baluchistan. Permo-Carboniferous Plants from Kashmir.

Part 2 (out of print).—Mineral Production of India during 1906. Ammonites of Bagh Beds. Miscellaneous Notes.

Part 3 (out of print).—Marine fossils in Yenangyaung oil-field, Upper Burma. Freshwater shells of genus Batissa in Yenangyaung oil-field, Upper Burma. New Species of Dendrophyllia from Upper Miocene of Burma. Structure and age of Taungtha hills, Myingyan district, Upper Burma. Fossils from Sedimentary rocks of Oman (Arabia). Rubies in Kachin hills, Upper Burma. Cretaceous Orbitoides of India. Two Calcutta Earthquakes of 1906. Miscellaneous Notes.

Part 4 (out of print).—Pseudo-Fucoids from Pab sandstones at Fort Munro, and from Vindhyan series. Jadeite in Kachin Hills, Upper Burma. Wetchok-Yedwet Pegu outcrop, Magwe district, Upper Burma. Group of Manganates, comprising Hollandite, Psilomelane and Coronadite. Occurrence of Wolfram in Nagpur district, Central Provinces. Miscellaneous Notes. Index to Volume XXXVI.

VOL. XXXVII, 1908-09.

Part 1 (out of print).—General report for 1907. Mineral Production of India during 1907. Occurrence of striated boulders in Blaini formation of Simla. Miscellaneous Notes.

Part 2 (out of print).—Tertiary and Post-Tertiary Freshwater Deposits of Baluchistan and Sind. Geology and Mineral Resources of Rajpipla State. Suitability of sands in Rajmahal Hills for glass manufacture. Three new Manganese-bearing minerals:—Vredenburgite, Sitaparite and Juddite. Laterites from Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Southern part of Gwegyo Hills, including Payagyigon-Ngashandaung Oil-field. Silver-lead mines of Bawdwin, Northern Shan States. Mud volcanoes of Arakan Coast, Burma.

Part 4.—Gypsum Deposits in Hamirpur district, United Provinces. Gondwanas and related marine sedimentary system of Kashmir. Miscellaneous Notes. Index to Volume XXXVII.

VOL. XXXVIII, 1909-10.

Part 1.—General report for 1908. Mineral Production of India during 1908.

Part 2 (out of print).—Ostrea latimarginata in "Yenangyaung stage" of Burma. China-clay and Fire-clay deposits in Rajmahal Hills. Coal at Gilhurria in Rajmahal hills. Pegu Inlier at Ondwe, Magwe district, Upper Burma. Salt Deposits of Rajputana. Miscellaneous Notes.

Part 3 (out of print).—Geology of Sarawan, Jhalawan, Mekran and the State of Las Bela. Hippurite-bearing Limestone in Seistan and Geology of adjoining region. Fusulinidæ from Afghanistan. Miscellaneous Notes.

Part 4.—Geology and Prospects of Oil in Western Prome and Kama, Lower Burma (including Namayan, Padaung, Taungbogyi and Ziaing). Recorrelation of Pegu system in Burma with notes on Horizon of Oil-bearing Strata (including Geology of Padaukpin, Banbyin and Aukmanein). Fossil Fish Teeth from Pegu system, Burma. Northern part of Yenangyat Oil-field. Iron Ores of Chanda, Central Provinces. Geology of Aden Hinterland. Petrological Notes on rocks near Aden. Upper Jurassic Fossils near Aden. Miscellaneous Notes. Index to Volume XXXVIII.

VOL. XXXIX, 1910.

Quinquennial Review of Mineral Production of India during 1904 to 1908 (*out of print*).

VOL. XL, 1910.

Part 1.—Pre-Carboniferous Life-Provinces. Lakes of Salt Range in the Punjab. Preliminary survey of certain Glaciers in Himalaya. D.—Notes on certain Glaciers in Sikkim. New Mammalian Genera and Species from Tertiaries of India.

Part 2 (out of print).—General Report for 1909. Mineral Production of India during 1909.

Part 3.—Revised Classification of Tertiary Freshwater Deposits of India. Revision of Silurian-Trias Sequence in Kashmir. Fenestella-bearing beds in Kashmir.

Part 4 (out of print).—Alum Shale and Alum Manufacture, Kalabagh, Mianwali district, Punjab. Coal-fields in North-Eastern Assam. Sedimentary Deposition of Oil. Miscellaneous Notes. Index to Volume XL.

VOL. XLI, 1911-12.

Part 1.—Age and continuation in Depth of Manganese-ores of Nagpur-Balaghat Area, Central Provinces. Manganese-ore deposits of Gangpur State, Bengal, and Distribution of Gondite Series in India. Baluchistan Earthquake of 21st October 1909. Identity of Ostrea Promensis, Noetling, from Pegu System of Burma and Ostrea Digitalina, Eichwald, from Miocene of Europe. Mr. T. R. Blyth. Miscellaneous Notes.

Part 2.—General Report for 1910. Devonian Fossils from Chitral, Persia, Afghanistan and Himalayas. Sections in Pir Panjal Range and Sind Valley Kashmir.

Part 3.—Mineral Production of India during 1910. Samarskite and other minerals in Nellore District, Madras Presidency. Coal in Namchik Valley, Upper Assam. Miscellaneous Notes.

Part 4.—Pegu-Eocene Succession in Minbu District near Ngape. Geology of Henzada District, Burma. Geology of Lonar Lake, with note on Lonar Soda Deposit. International Geological Congress of Stockholm. Miscellaneous Notes. Index to Volume XLI.

VOL. XLII, 1912.

Part 1.—Survival of Miocene Oyster in Recent Seas. Silurian Fossils from Kashmir. Blödite from Salt Range. Gold-bearing Deposits of Mong Long, Hsipaw State, Northern Shan States, Burma. Steatite Deposits, Idar State. Miscellaneous Notes.

Part 2.—General Report for 1911. Dicotyledonous Leaves from Coal Measures of Assam. Poting Glacier, Kumaon, Himalaya, June 1911. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1911. Kodurite Series.

Part 4.—Geological Reconnaissance through Dehong Valley, being Geological Results of Abor Expedition, 1911-12. Traverse across the Naga Hills of Assam. Indian Aerolites. Miscellaneous Notes.

VOL. XLIII, 1913.

Part 1 (out of print).—General Report for 1912. Garnet as a Geological Barometer. Wolframite in Tavoy District, Lower Burma. Miscellaneous Notes.

Part 2 (out of print).—Mineral Production of India during 1912. Relationship of the Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Hambergite from Kashmir.

Part 3.—Contributions to the geology of the Province of Yünnan in Western China: I.—Bhamo-Têng-Yüeh Area. II.—Petrology of Volcanic Rocks of Têng-Yüeh District. The Kirna Hills. Banswal Aerolite.

Part 4.—Gold-bearing Alluvium of Chindwin River and Tributaries. Correlation of Siwalik with Mammal Horizons of Europe. Contributions to the Geology of the Province of Yünnan in Western China : III.—Stratigraphy of Ordovician and Silurian Beds of Western Yünnan, with Provisional Palæontological Determinations. Notes on "Camarocrinus Asiaticus" from Burma.

Vol. XLIV, 1914.

Part 1 (out of print).—General Report for 1913. Carbonaceous Aërolite from Rajputana. Nummulites as Zone Fossils, with description of some Burmese species.

Part 2.—Contributions to the Geology of the Province of Yünnan in Western China : IV.—Country around Yünnan Fu. Dyke of white Trap from Pench Valley Coal-field, Chhindwara District, Central Provinces. Mineral concessions during 1913.

Part 3.—Coal-seams near Yaw River, Pakokku District, Upper Burma. The Monazite Sands of Travancore. Lower Cretaceous Fauna from Himalayan Gieumal Sandstone together with description of a few fossils from Chikkim series. *Indarctos salmontanus* Pilgrim. Future Beheading of Son and Rer Rivers by Hasdo.

Part 4.—Salt Deposits of Cis-Indus Salt Range. Teeth referable to Lower Siwalik Creodont genus 'Dissopsalis' Pilgrim. Glaciers of Dhauli and Lisar Valleys, Kumaon, Himalaya, September 1912. Miscellaneous Notes.

Vol. XLV, 1915.

Part 1.—New Siwalik Primates. Brachiopoda of Namyau Beds of Burma. Miscellaneous Note.

Part 2.—General Report for 1914. Note on Sivælurus and Paramachærodus.

Part 3.—Mineral Production of India during 1914. Three New Indian Meteorites, Kuttippuram, Shupiyan and Kamsagar. Dentition of Tragulid Genus (Dorcabune). Hematite Crystals of Corundiform Habit from Kajlidongri, Central India.

Part 4.—Geology of country near Ngahlaingdwin. Geology of Chitral, Gilgit and Pamirs.

Vol. XLVI, 1915.

Quinquennial Review of Mineral Production of India for 1909 to 1913 *(out of print)*.

Vol. XLVII, 1916.

Part 1.—General Report for 1915. Eocene Mammals from Burma. Miscellaneous Notes.

Part 2.—The Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Iron Ore Deposits of Twinngé, Northern Shan States.

Part 3.—Obituary : R. C. Burton. The Mineral Production of India during 1915. Flemingostrea, an eastern group of Upper Cretaceous and Eocene Ostreidæ, with descriptions of two new species.

Part 4.—Contributions to the Geology of the Province of Yünnan in Western China : 5.—Geology of parts of the Salween and Mekong Valleys. A fossil wood from Burma. The Visuni and Ekh Khera Aerolites.

Vol. XLVIII, 1917.

Part 1.—General Report for 1916. A revised classification of the Gondwana System.

Part 2.—Mineral Production of India during 1916. Mammal collections from Basal Beds of Siwaliks.

Part 3.—Crystallography and Nomenclature of Hollandite. Geology and Ore Deposits of Bawdwin Mines. Miscellaneous Notes.

Part 4.—Biana-Lalsot Hills in Eastern Rajputana. Origin of the Laterite of Seoni, Central Provinces.

Vol. XLIX, 1918-19.

Part 1.—General Report for 1917. Cassiterite Deposits of Tavoy. Les Echinides des "Bagh Beds."

Part 2.—Mineral Production of India during 1917. Support of Mountains of Central Asia.

Part 3.—Structure and Stratigraphy in North-West Punjab. Aquamarine Mines of Daso, Baltistan. Srimangal Earthquake of July 8th, 1918.

Part 4.—Possible Occurrence of Petroleum in Jammu Province : Preliminary Note on the Nar-Budhan Dome, of Kotli Tehsil in the Punch Valley. Submerged Forests at Bombay. Infra-Trappeans and Silicified Lava from Hyderabad, S. India.

Vol. L, 1919.

Part 1.—General Report for 1918. Potash Salts of Punjab Salt Range and Kohat. Origin and History of Rock-salt Deposits of Punjab and Kohat.

Part 2.—Tungsten and Tin in Burma. Inclination of Thrust-plane between Siwalik and Murree zone near Kotli, Jammu. Two New Fossil Localities in Garo Hills. Sanni Sulphur Mine. Miscellaneous Notes.

Part 3 (out of print).—Mineral Production of India during 1918. Gastropoda Fauna of Old Lake-beds in Upper Burma. Galena Deposits of North-Eastern Putao.

Part 4.—Pitchblende, Monazite and other minerals from Pichhli, Gaya district Bihar and Orissa. Natural Gas in Bituminous Salt from Kohat. Mineral Resources of Central Provinces. Miscellaneous Notes.

Vol. LI, 1920-21.

Part 1.—General Report for 1919. Pseudo-crystals of Graphite from Travancore. Mineral related to Xenotime from Manbhum District, Bihar and Orissa Province. Coal Seams of Foot-Hills of the Arakan Yoma, between Letpan Yaw in Pakokku and Ngapé in Minbu, Upper Burma. Observations on "Physa Prinsepii," Sowerby and on a Clionid Sponge that burrowed in its shell.

Part 2.—Classification of fossil Cypræidæ. Sulphur near the confluence of the Greater Zab with the Tigris, Mesopotamia. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1919. Results of a Revision of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma. Marine Fossils collected by Mr. Pinfold in the Garo Hills.

Part 4.—Illustrated comparative Diagnoses of Fossil Terebridæ from Burma. Indian Fossil Viviparæ. New fossil Unionid from the Intertrappean beds of Peninsular India. Unionidæ from the Miocene of Burma.

Vol. LII, 1921.

Quinquennial Review of Mineral Production of India for 1914-1918.

Vol. LIII, 1921.

Part 1.—General Report for 1920. Antimony deposit of Thabyu, Amherst district. Antimony deposits of Southern Shan States. Geology and Mineral Resources of Eastern Persia. Miscellaneous Notes.

Part 2.—Comparative Diagnoses of Pleurotomidæ from Tertiary Formation of Burma. Comparative Diagnoses of Conidæ and Cancellariidæ from Tertiary of Burma. Stratigraphy, Fossils and Geological Relationships of Lameta Beds of Jubbulpore. Rocks near Lameta Ghat (Jubbulpore District).

Part 3 (out of print).—Obituary: Frederick Richmond Mallet. Mineral Production of India during 1920. Mineral Resources of Bihar and Orissa.

Part 4.—Stratigraphy of the Singu-Yenangyat Area. Analysis of Singu Fauna. Sulphur Deposits of Southern Persia. A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica.

Vol. LIV, 1922.

Part 1.—General Report for 1921. Contributions to the Geology of the Province of Yünnan in Western China: VI.—Traverses between Tali Fu and Yunnan Fu. Geology of Takki Zam Valley, and Kaniguram-Makin Area, Waziristan. Geology of Thayetmyo and neighbourhood, including Padaukbin. Bitumen in Bombay Island.

Part 2.—Mineral Production of India during 1921. Iron Ores of Singhbhum and Orissa. Geological Results of Mount Everest Reconnaissance Expedition. Northern Extension of Wolfram-bearing Zone in Burma. Miscellaneous Note.

Part 3.—Obituary: Rupert William Palmer. Indian Tertiary Gastropoda. IV.—Olividæ. Harpidæ, Marginellidæ, Volutidæ and Mitridæ, with comparative diagnoses of new species. Structure of Cuticle in Glossopteris angustifolia Brongn. Revision of some Fossil Balanomorph Barnacles from India and the East Indian Archipelago. Contributions to the Geology of the Province of Yünnan in Western China: 7.—Reconnaissance Surveys between Shunning Fu, Chingtung Ting and Tali Fu. 8.—Traverse down Yang-tze-chiang Valley from Chin-chaing-kai to Hui-li-Chou. Boulder Beds beneath Utatur State, Trichinopoly District. Miscellaneous Notes.

Part 4.—Geology of Western Jaipur. Geological Traverses from Assam to Myitkyina, through Hukong Valley; Myitkyina to Northern Putao; and Myitkyina to Chinese Frontier. Oligocene Echinoidea collected by Rao Bahadur S. Sethu Rama Rau in Burma. Mineral Resources of Kolhapur State. Kunghka and Manmaklang Iron Ore Deposits, Northern Shan States, Burma.

VOL. LV, 1923-24.

Part 1.—General Report for 1922. Indian Tertiary Gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ, Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species. Geological Interpretation of some Recent Geodetic Investigations (being a second Appendix to the Memoir on the structure of the Himalayas and of the Gangetic Plain as elucidated by Geodetic Observations in India).

Part 2.—Obituary: Ernest (Watson) Vredenburg. Fossil Molluscs from Oil-Measures of Dawna Hills, Tenasserim. Armoured Dinosaur from Lametta Beds of Jubbulpore. Fossil forms of Placuna. Phylogeny of some Turbinellidæ. Recent Falls of Aerolites in India. Geology of part of Khasi and Jaintia Hills, Assam.

Part 3.—Mineral Production of India during 1922. Lignitic Coal-fields in Karewa formation of Kashmir Valley. Basic and Ultra-Basic Members of the Charnockite Series in the Central Provinces. China Clay of Karalgi, Khanapur, Belgaum District.

Part 4.—Obituary: Henry Hubert Hayden. Oil Shales of Eastern Amherst, Burma, with a Sketch of Geology of Neighbourhood. Provisional list of Palæozoic and Mesozoic Fossils collected by Dr. Coggin Brown in Yünnan. Fall of three Meteoric Irons in Rajputana on 20th May 1921. Miscellaneous Note.

VOL. LVI, 1924-25.

Part 1.—General Report for 1923. Mineral Deposits of Burma.

Part 2.—Mineral Production of India during 1923. Soda rocks of Rajputana.

Part 3.—Gyrolite and Okenite from Bombay. Freshwater Fish from oil-measures of Dawna Hills. Fossil Ampullariid from Poonch, Kashmir. Calcareous Alga belonging to Triploporelleæ (Dasycladaceæ) from Tertiary of India. Froth Flotation of Indian Coals. Submarine Mud Eruptions off Arakan Coast, Burma. Cretaceous Fossils from Afghanistan and Khorasan.

Part 4.—Merua Meteorite. Stegodon Ganesa in Outer Siwaliks of Jammu. Land and Freshwater Fossil Molluscs from Karewas of Kashmir. Burmese Lignites from Namma, Lashio and Pauk. Maurypur Salt Works.

VOL. LVII, 1925.

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Part 1.—General Report for 1924. Fossil Tree in Panchet Series of Lower Gondwanas near Asansol, with Palæontological Description.

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Part 3.—Mineral Production of India during 1924. Enstatite-Augite Series of Pyroxenes. Constitution of the Glauconite and Celadonite. Palagonite-bearing Dolerite from Nagpur.

Part 4.—Fossils Crétacés de l'Afghanistan. Fossiles du Kashmir et des Pamirs. Additions and Corrections to Vredenburg's Classification of the Cypræidæ. Petrology of Rocks from Girnar and Oshan Hills, Kathiawar, India.

VOL. LIX, 1926.

Part 1.—General Report for 1925. Foraminifora of parts of Western India.

Part 2.—Sampling Operations in Pench Valley Coal-field. Composition of some Indian Garnets. Geology of Andaman and Nicobar Islands, with special reference to Middle Andaman Island. Occurrence of Cryptohalite. Remarks on Carter's Genus Conulites.

Part 3.—Mineral Production of India during 1925. Metamorphic Rocks and Intrusive Granite of Chhota Udepur State. Indian Species of Conoclypeus.

Part 4.—Low-Phosphorus Coking Coal in Giridih Coal-Field. Distribution of Gault in India. Age of so-called Danian Fauna from Tibet. Bauxite on Korlapat Hill, Kalahandi State, Bihar and Orissa.

VOL. LX, 1927-28.

Part 1.—General Report for 1926. Six Recent Indian Aërolites.

Part 2.—Gas Eruption on Ramri Island, off Aracan Coast of Burma, in July, 1926. Oil Indications at Drigh Road near Karachi. Lower Canine of Tetraconodon. Geology of Bundi State, Rajputana.

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Vol. LXI, 1928-29.

Part 1.—General Report for 1927. Actionodon risinensis in Lower Gondwanas of Vihi district, Kashmir. Miscellaneous Note: Further Note on Nomenclature of Hollandite.

Part 2.—Contribution to Geology of Punjab Salt Range. Iron Ore Deposits of Northern Shan States. Lower Canine of Indian Species of Conohyus. Miscellaneous Note: Leucopyrite from Kodarma.

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Vol. LXII, 1929-30.

Part 1.—General Report for 1928. Miscellaneous Note: New Chromite Localities.

Part 2.—Obituary: Sivaram Sethu Rama Rau. Specific Gravity and Proximate Composition of Indian Vitrains. New Devonian Fossils from Burma. Rangoon Earthquakes of September and December 1927. Epicentre of North-West Himalayan Earthquake of 1st February 1929. Miscellaneous Notes: Indian Beryl, Atacamite in Bihar and Pyromorphite in Bhagalpur district, Bihar.

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Vol. LXIII, 1930.

Part 1.—General Report for 1929. Upper Triassic Fossils from Burmo-Siamese Frontier.—Thaungyin Trias and Description of Corals. Upper Triassic Fossils from Burmo-Siamese Frontier.—Brachiopoda and Lamellibranchia from Thaungyin River. Upper Triassic Fossils from Burmo-Siamese Frontier.—Fossils from Kamawkala Limestone. Upper Triassic Fossils from Burmo-Siamese Frontier.—New Dasycladaceæ, *Holosporella siamensis* nov. gen., nov. sp., with Description of Allied Genus *Aciculella* Pia. Cretaceous Cephalopods in 'Red Beds' of Kalaw, Southern Shan States, Burma.

Part 2.—Methods of Analysis of Coal used at Government Test House, Alipore, Calcutta, with an Editorial Introduction. New fossil localities within Panchet series of Raniganj Coalfield. Species of *Cyllene* from Pegu Beds of Burma. Two new species of *Unio*. Glaciers of Karakoram and Neighbourhood. Miscellaneous Note: Dome near Mari in Attock District.

Part 3.—Mineral Production of India during 1929. On the Specific Gravity and Proximate Composition of some Indian Durains.

Part 4.—Aspects of Modern Oil Field Practice. Undescribed freshwater Molluscs from various parts of India and Burma. Second note on North-West Himalayan Earthquake of 1st February, 1929. Miscellaneous Notes: Tremolite from near Jasidih, Bihar, Sapphirine in Visagapatam District and Titaniferous Augite from Chandrawati, Sirohi State, Rajputana.

Vol. LXIV, 1930.

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Vol. LXV, 1931-32.

Part 1.—General Report for 1930. Additional Note on Samelia Meteorite. Zoning and Difference in Composition of Twinned Plagioclase Felspars in certain rocks from Sirohi State, Rajputana. Albite-Ala B Twinning of Plagioclase Felspars in certain acidic rocks from Sirohi State, Rajputana. Jurassic Fossils from Northern Shan States.

Part 2.—Syntaxis of North-West Himalayas: Its Rocks, Tectonics and Orogeny. Preliminary Note on Pegu Earthquake of May 5th, 1930. Determination from World Records of Zero-time and Epicentre of Pegu Earthquake of May 5th, 1930. Long Distance Wave Speeds of Pegu Earthquake of May 5th, 1930. Rocks bearing Kyanite and Sillimanite in Bhandara District, C. P. Stratigraphy of Upper Ranikot Series (Lower Eocene) of Sind, India. Miscellaneous Note: Fuchsite Vase from Mohenjo Daro (Sind).

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Part 4.—Reaction Minerals in Garnet-Cordierite Gneiss from Mogok. Vindhyans of western Rajputana. Granitic Intrusions in Ranchi and Singhbhum Districts. Miscellaneous Notes: *Chonetes* in Krol Limestone; Green Mica from Bhandara District; and Olivine-Basalt and Tuffs in Malaní Series at Jodhpur.

Vol. LXVI, 1932-33.

Part 1.—General Report for 1931. Rudistæ from Eastern Persia.

Part 2.—Lower Palæozoic Fossils from the Southern Shan States. Geology of Nanga Parbat (Mt. Diamir) and adjoining portions of Chilas, Gilgit District, Kashmir. Fossil Plants from Parsora Stage, Rewa. Swa Earthquake of August 8th, 1929. Overlap in the Ngape Area, Minbu District. Miscellaneous Note: Ammonite from Ramri Island.

Part 3. Mineral Production of India during 1931. Microscopic Study of some Indian Coals. Specific Gravity and Porosity of Indian Building Stones. Indian Seismological Records of Chief Shocks in N.-E. Frontier Region of Burma during 1929 and 1930. Glacier in Arwa Valley, Garhwal.

Part 4.—Fusulinids of Lower Productus Limestone of Salt Range. *Dadoxylon zalesskyi*, a new Species of Cordaitean trees from Lower Gondwanas of India. Fossil Pentalocular Fruit from Pondicherry. Kalava (Calwa) 'Wall' in Kurnool District. Talc-Serpentine-Chlorite Rocks of Southern Mewar and Dungarpur. Age of certain Himalayan Granites. Tables of Production, Imports, Exports and Consumption of Minerals and Metals in India.

Vol. LXVII, 1933.

Part 1.—General Report for 1932. Anthracolithic Faunas of Southern Shan States.

Part 2.—Geological Reconnaissance in Southern Shan States. Geology of the country between Kalaw and Taunggyi.

Part 3.—Mineral Production of India during 1932. Geological Notes on Traverses in Tibet made by Sir Henry Hayden in 1922. Origin of Streaky Gneisses of Nagpur District.

Part 4.—Geology of the Krol Belt. Crush Conglomerates of Dharwar Age from Chota Nagpur and Jubbulpore.

Vol. LXVIII, 1934-35.

Part 1.—General Report for 1933. Obituary: Malhari Vinayak Rao. Khanpur Meteoric Shower. Cambrian Sequence of Punjab Salt Range.

Part 2.—Cambrian-Trias Sequence of North Western Kashmir (Parts of Muzaffarabad and Baramula Districts). Preliminary account of Earthquake of 15th January, 1934, in Bihar and Nepal Obituary: Pramatha Nath Bose. Miscellaneous Notes: Barytes in Manbhum District, Bihar; Soda Deposit and Manufacture of Caustic Soda and Crude Soap at Parantij, Ahmedabad District; Potash content of *Reshta*, Sambhar Salt Lake, Rajputana; Alunogen from Cuddapah District; and Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1934.

Part 3.—Mineral Production of India during 1933 Manganese Lime Series of Garnets. Chemical Composition of Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1934

Part 4.—Soils of India. Lateritisation of Khondalite. Snout of Biafo Glacier in Baltistan. Turonian Ammonite (*Mammites Daviesi*) from Ramri Island, Burma. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1934; Tertiary Rocks near Puri; and Cretaceous and Eocene Volcanic Rocks of the Great Himalaya Range in North Kashmir.

Vol. LXIX, 1935-36.

Part 1.—General Report for 1934. Primitive Fossils, possibly Atrematous and Neotrematous Brachiopoda, from the Vindhyans of India. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1934 and Additional Note on Nomenclature of Hollandite.

Part 2.—Traverses in Himalaya. Jabalpur Plants from Satpura-Gondwana Basin. *Rhizomopsis* Gothan and Sze and *Dictyopteridium* Feistmantel. Sphærosiderite, containing a New Species of *Dadoxylon* (*D. parbeliense*), from Lower Gondwana Coal Measures of India. Earthquakes recorded by the Pendulum Seismograph at Shillong (Assam) from 1903 to 1931. Preliminary Geological Report on Baluchistan (Quetta) Earthquake of May 31st, 1935. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1935 and Gypsum in Upper Vindhyans of Rajputana.

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Part 4.—Buchanan's Laterite of Malabar and Kanara. Solubility of Quartz. Natural Gas at Gogha, Kathiawar. Patwar Meteoric Shower of the 29th July, 1935. *Fermoria minima*: A Revised Classification of Organic Remains from Vindhyans of India. Ore minerals from Bawdwin, Shan States. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1935.

Vol. LXX, 1936.

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Vol. 71, 1936.

Part 1.—General Report for 1935. Dyke Rocks of Keonjhar State, *Bihar* and *Orissa*. *Miscellaneous* Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1935.

Part 2.—Perpeti Meteoric Shower of 14th May, 1935. Tirupati and Bahjoi Meteorites. *Ostrea* (*Crassostrea*) *gajensis* from near Baripada, Mayurbhanj State. *Matonidium* and *Weichselia* in India. Cretaceous Cephalopods from Red Beds of Kalaw and Age of Red Beds. Contributions to the Geology of the Province of Yunnan in Western China; 9.—Brachiopod Beds of Liu-wun and related formations in Shan States and Indo-China. Geological Age of Namyau, Liu-wun and Napeng Beds and of Certain other formations in Indo-China. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1936.

Part 3.—Mineral Production of India during 1935. Marble of the North-West Frontier Province. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1936.

Part 4.—Obituary: Richard Dixon Oldham. Geology of Second Defile of Irrawaddy River. *Orbitolina*-bearing rocks in Burma: with description of *Orbitolina birmanica*, sp. nov. Rocks in vicinity of Kyaukse, Burma. Mesozoic coniferous wood (*Mesembrioxylon shanense*, sp. nov.) from Southern Shan States of Burma. Foraminifera from Inter-trappean Beds near Rajahmundry. *Holosporella* cf. H. *Siamensis Pia*, from Rajahmundry Limestones. Maleri beds of Hyderabad State (Deccan) and Tiki Beds of South Rewa. Structure of Himalaya in Garhwal. Miscellaneous Notes: Coaly Shale in Deccan Trap in Indore, Central India. Octahedral Pyrite Crystals from Kohat District, North-West Frontier Province. Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1936.

Vol. 72, 1937.

Part 1.—General Report for 1936. Note on 'coalite' Freshwater and Land Fossil Mollusca from near Ghorband, Afghanistan. Provisional statistics of some of the more important Indian Minerals for 1936. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: October to December, 1936.

Part 2.—Snout of Gangotri Glacier, Tehri Garhwal. Petroleum Technology in Burma during 1936 with special reference to Protection of Oil and Gas Sands. Cretaceous Volcanic Series of Astor-Deosai, Kashmir, and its Intrusions. Permo-Carboniferous Limestone Inliers in Sub-Himalayan Tertiary Zone of Jammu, Kashmir Himalaya. Shark Tooth from Lower Eocene. Fossil Fish-remains from Karewas of Kashmir. Fossil Fish-remains from Saline Series of North-Western India. Fossil Plants from Po Series of Spiti (N. W. Himalayas). Polished and Thin Section Technique in Laboratory of Geological Survey of India. Marble and Dolomite of Gundai Tarako, North-West Frontier Province. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1937.

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VOL. 73, 1938.

Part 1.—General Report for 1937. Hindu Kush Earthquake of 14th November, 1937. Khoobarite, a New Garnet and on the Nomenclature of Garnets. Provisional Statistics of some of the more important Indian minerals for 1937. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India including Burma: October to December, 1937.

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VOL. 74, 1939.

Part 1.—General Report for 1938. Structure of the Shali Window near Simla. Provisional Statistics of some of the more important-Indian minerals for 1938. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India and Burma: October to December, 1938.

Part 2 (in the press).—The Lachi Series of North Sikkim and the age of the rocks forming Mount Everest. Note on Dunghan Limestone. Fossil Fish from Balasore. Note on Echinoidea from Burma. The underground water supply of the Peshawar and Mardan districts of the North-West Frontier Province with an appendix on the Kohat Valley. The Rangala meteorite. Miscellaneous Notes. Quarterly Statistics of Production of Coal, Gold, and Petroleum in India: January to March 1939.

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